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In re Application of **Young** | Atty. Docket No.: **GB 010051**
Serial No.: **10/084,723** | Group Art Unit: **2826**
Filed: **2/25/2002** | Examiner: **Mandala, Victor A**
Title: **MATRIX ARRAY DEVICES WITH FLEXIBLE SUBSTRATES**

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REPLY BRIEF

Sir:

This is a response to the Examiner's Answer, dated 16 January 2004, to the applicant's Appeal Brief, dated 5 November 2003.

Claims 1-3, 6, 8-11, and 13 are rejected under 35 U.S.C. 102(e) over Nishizawa et al. (USP 6,323,832, hereinafter Nishizawa); claims 4-5 are rejected under 35 U.S.C. 103(a) over Nishizawa; claims 7 and 12 are are rejected under 35 U.S.C. 103(a) over Nishizawa and Shanks et al. (USP 5,821,688, hereinafter Shanks).

The applicant notes that a rejection of claims 14 and 15 has not been presented by the Examiner, and therefore presumes that these claims are allowable.

In the Examiner's Answer, the Examiner states: "Since the independent claims do not specifically claim and refer to the Applicant's disclosed device, the examiner finds the arguments [presented in the applicant's Appeal Brief] to be non-persuasive on this basis." (Examiner's Answer, page 9, first paragraph.) The applicant respectfully traverse this characterization of the applicant's arguments.

In the applicant's Appeal Brief, the applicant specifically refers to the elements of independent claims 1 and 2, and in particular to an array device having semiconductor devices in a first area of a substrate and pixel electrodes located in a second area of the substrate, wherein the substrate is configured to flex in the second area (Brief, page 3,

first paragraph). The basis of the applicant's argument is that Nishizawa does not distinguish between areas in which semiconductor devices are placed, and areas in which pixel electrodes are placed, and thus cannot be said to teach a substrate that is configured to flex beneath one of these distinguished areas (Brief, page 3, third paragraph).

In the Examiner's Answer, the Examiner states that Nishizawa teaches LEDs that "are coupled together by wires, (pixel electrodes, wherein electrodes are used to electrically couple devices together). The Appellant's claim language does not teach the pixel electrodes to be defined by the specific and narrowed art of TFTs and LCDs as being argued by the Applicant." (Answer, page 9, lines 6-9.) The applicant respectfully traverses this characterization of Nishizawa's wires between LEDs as "pixel electrodes", and traverses the assertion that the term "pixel electrode" is defined by the specific and narrowed art of TFTs and LCDs.

Nishizawa does not refer to "pixel electrodes". The applicant respectfully maintains that the term "pixel electrode" as used and defined in the application, and as commonly used in the art, does not support a reading of the claims that includes Nishizawa's ***wires between pixels*** being called ***pixel electrodes***, as proposed by the Examiner. "Claim language generally carries the ordinary meaning of the words in their normal usage in the field of invention." *Invitrogen Corp. v. Biocrest Mfg., L.P.*, 327 F.3d 1364, 1367 (Fed. Cir. 2003). Although it is improper to read a limitation from the specification into the claims, *Comark Communications, Inc. v. Harris Corp.*, 156 F.3d 1182, 1186 (Fed. Cir. 1998), "[c]laims must be read in view of the specification, of which they are a part," *Markman*, 52 F.3d at 979; see also *United States v. Adams*, 383 U.S. 39, 49 (1966) ("[C]laims are to be construed in the light of the specifications and both are to be read with a view to ascertaining the invention."); *Slimfold Mfg. Co. v. Kinkead Indus., Inc.*, 810 F.2d 1113, 1116 (Fed. Cir. 1987) ("Claims are not interpreted in a vacuum, but are part of and are read in light of the specification.")" (*Microsoft Corp. v. Multi-Tech Systems, Inc.*, Slip Op. 03-1138, Fed. Cir., 3 February 2004).

The applicant defines a pixel electrode as the element 18 illustrated in FIGs. 2, 3, and 6 (applicant's specification, page 6, line 5; page 8, line 15; and page 13, line 4, respectively). As illustrated in FIG. 2, the defined "pixel electrode" is the electrode that

controls the state of each pixel. A "pixel electrode" defines each pixel (picture element), because the region at each pixel electrode is controlled to provide the elements that form the picture. As illustrated in FIGs. 3 and 6, the defined "pixel electrodes" are separate and distinct from the column and row wires 14 and 16 that connect adjoining pixels along the column and row axes. This defined definition of "pixel electrode" is clear from the applicant's specification, and consistent with the term as used in the art. Although the applicant's example embodiment is an LCD device, wherein the pixel electrode controls the opacity of the liquid crystal material, the term pixel electrode is also used in other fields wherein individual picture elements (pixels) are used.

The applicant searched the Internet for the term "pixel electrode". A sampling of the hundreds of articles identified by the search confirmed the conventional use of the term "pixel electrode" to be the electrode that forms each light-controlling, light-sensing, or light-emitting picture element. This definition was consistent among articles dealing with Liquid Crystal Displays (including TFT and Pin-diode LCDs), Field Emitter Array (FEA) sensors, X-ray detectors, and Image Light Amplifier (ILA) projectors. In image sensing, each pixel electrode defines the area that is sensed to provide the individual elements (pixels) that form the picture. Seven of these sampled articles are attached; dozens of others can be provided upon request. The applicant respectfully notes that none of the sampled articles refer to the wires between the pixels as "pixel electrodes".

As defined by the applicant, and consistent with the conventional use of the term "pixel electrode", a pixel electrode 18 defines each picture element (pixel), and does not correspond to the wire that interconnect the pixels. The applicant maintains that although Nishizawa does not refer to "pixel electrodes", any pixel electrodes that are present in Nishizawa are contained within Nishizawa's LEDs, and not in the wires that interconnect Nishizawa's LEDs. The applicant claims a flexible matrix array device with a substrate that is configured so that flexing of the substrate occurs ***at*** the pixel electrodes; Nishizawa teaches the flexing of a substrate in the regions ***between*** pixel electrodes, as the term "pixel electrode" is defined in the applicant's specification, and as the term "pixel electrode" is commonly used in the art.

Because the applicant's specification clearly distinguishes pixel electrodes from the conductors that interconnect the pixels, and because the applicant's specification is

consistent with the conventional use of the term pixel electrode, the applicant respectfully maintains that the Nishizawa's wires that interconnect Nishizawa's LEDs cannot reasonably be said to correspond to the applicant's claimed pixel electrodes.

In the Examiner's Answer, the Examiner uses Webster's definition of "electrode" to support the assertion that the wires between Nishizawa's pixels correspond to the applicant's claimed pixel electrodes. The applicant respectfully traverses this use of a definition of a single word (electrode) to define the meaning of a word-phrase (pixel electrode), particularly when the word-phrase has a consistent and common usage in the field.

Further, assuming in argument the Examiner's definition of 'electrode' from Webster: "a conductor used to establish electrical contact with a ***nonmetallic*** part of a circuit" (which is consistent with the applicant's defined pixel electrode that establishes contact with the nonmetallic LCD material that forms each pixel), the applicant respectfully maintains that Nishizawa's wire 2 that interconnects the pixels cannot be said to be an "electrode" as defined by Webster, because Nishizawa's wire 2 does not connect to a nonmetallic part of a circuit.

As illustrated in Nishizawa, the wire 2 is a conductor that establishes contact with each pixel device 1a, 2a, 3a, etc. The Examiner's Answer acknowledges that Nishizawa's wires "are used to electrically couple devices together" (Answer, page 9, line 7). As illustrated in Nishizawa's figures, the pixel devices are discrete elements, which Nishizawa exemplifies as light-emitting diodes (LEDs) (Nishizawa, column2, lines 30-33). As is known to one of ordinary skill in the art, conventional LEDs use metallic conductors (pins) to connect the internal elements of the LED to the wires that provide the activation signals to the LED. Light emitting 'chips', as referenced by Nishizawa (column 2, lines 50-61), are also connected to external wires via metallic pads. Thus, absent any evidence to the contrary, the wire 2 of Nishizawa must be connected to a ***metallic*** conductor (pin or pad) of each LED, and not to "a ***nonmetallic*** part", as Webster's definition of an "electrode" requires.

Because Webster's definition of electrodes implicitly excludes conductors that interconnect conventional discrete electrical components, the applicants maintain that the wires 2 of Nishizawa that interconnect Nishizawa's discrete pixel elements cannot be said to correspond to the applicant's claimed pixel electrodes.

Because each of the applicant's independent claims includes a substrate that is configured to be flexed at ***the area of each pixel electrode***, and Nishizawa teaches flexing a substrate in areas ***between each pixel***, the applicant respectfully requests that the Examiner's rejection of claims 1-13 under 35 U.S.C. 102(e) and 35 U.S.C. 103(a) be reversed by the Board, and claims 1-15 be allowed to pass to issue.

Respectfully submitted,

Robert M. McDermott, Esq.
Reg. No. 41,508
804-493-0707

CERTIFICATE OF MAILING OR TRANSMISSION

It is hereby certified that, on the date shown below, this correspondence is being:

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On 8 March 2004 By __________

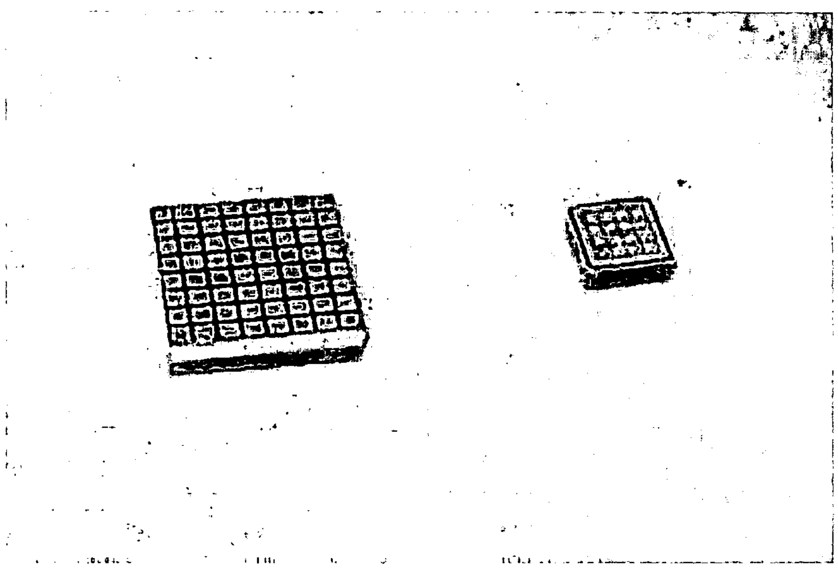
CZT Detector Development

Cadmium Zinc Telluride (CZT) is a high Z, large bandgap, semiconductor which shows excellent promise as a hard X-ray detector. The material has good electron transport properties, and the spectroscopic performance surpasses that of regular scintillators. By adding othogonal strip electrodes on two faces, or an array of pixel electrodes on one face, a single wafer can be segmented into a position sensitive detector for use in an imaging telescope.

At Harvard-Smithsonian Center for Astrophysics, we are developing pixellated CZT detectors for our next balloon-borne coded aperture telescope, *EXITE3*, and possibly for *EXIST*. We are currently optimizing the pixel electrode dimensions, and studying to see whether the addition of steering electrodes around the pixels improves charge collection.

We are also studying the effectiveness of blocking contacts on CZT. By creating a P-I-N contacts on CZT, we can reduce the amount of leakage current and improve the spectroscopic resolution.

We carried a small CZT experiment on the last *EXITE2* science flight in Spring of 1997. The experiment was designed to record the background spectrum in the CZT, in a configuration similar to what would be expected in a large field-of-view telescope. On our next *EXITE2* flight, we will carry two tiled 16 pixel detectors which will be read out by a single 32 channel preamplifier ASIC.



ACTIVE MATRIX LCDs

Introduction

To circumvent the reduction of contrast with increasing number of lines, Lechner et al. (1971) proposed to incorporate a switch at each picture element in a matrix display so that the voltage across each pixel could be controlled independently and the same high-contrast ratio of 100 or more, obtained in simple direct- driven displays, could in principle also be achieved for high-information-content displays.

The switch can be either a diode (two-terminal device) or a transistor (three-terminal device). Displays based on this principle are active matrix LCDs. Their fabrication requires the deposition and patterning of various metals, insulators, and semiconductors on glass substrates, comparable to the processing of integrated circuits. Brody et al. (1971) constructed the first AMLCD using CdSe thin-film transistors as the switching elements. In 1981 the first AMLCD with thin-film metal- insulator-metal diodes as the pixel switches was reported (Baraff et al. 1981). MIM diodes seemed particularly attractive for this application because they are relatively simple to fabricate and have current-voltage characteristics that are symmetric with respect to opposed polarities.

Poly-crystalline silicon (p-Si) and amorphous silicon (a-Si) devices were developed for use in AMLCDs in the early 1980s. The first LC pocket television marketed in 1984 used a p-Si TFT active matrix (Morozumi 1984). Most p-Si processes require high- temperature processing and therefore use expensive quartz substrates, but they offer the potential of integrating the drive electronics on the glass substrate.

Amorphous silicon can be easily deposited on large area inexpensive glass substrates at a temperature below 350 degrees centigrade, and can be doped p-type and n-type. *Pin* diodes of amorphous silicon for solar cells were developed in 1975, and their rectification ratio was improved to allow application as switches in AMLCDs (Yaniv et al. 1986b).

The first semiconductor used for TFTs in AMLCD application was CdSe. At the time, CdSe technology was not compatible with standard processing in the microelectronics industry, which uses mainly silicon as the semiconductor material. Advanced photolithographic and etching processes were adapted recently to CdSe with some very promising results (Farrell and Price 1992). LeComber et al. (1979) developed the first TFT with a-Si as the semiconductor material and suggested, as one of its applications, the active matrix LCD. In the 1980s, several companies, particularly in Japan, developed a-Si TFT LCDs, mainly for pocket TVs with 3-5" screens. Prototype displays with a diagonal size of 15" (Wada et al. 1990) and 17" were demonstrated (Sharp 1992).

Two- and Three-Terminal Devices

TFT Displays. Thin-film transistors with amorphous silicon, polycrystalline silicon, and CdSe film as the semiconductor material have been developed to function as the pixel switch. The layout of a TFT is schematically shown in Figure 3.3.

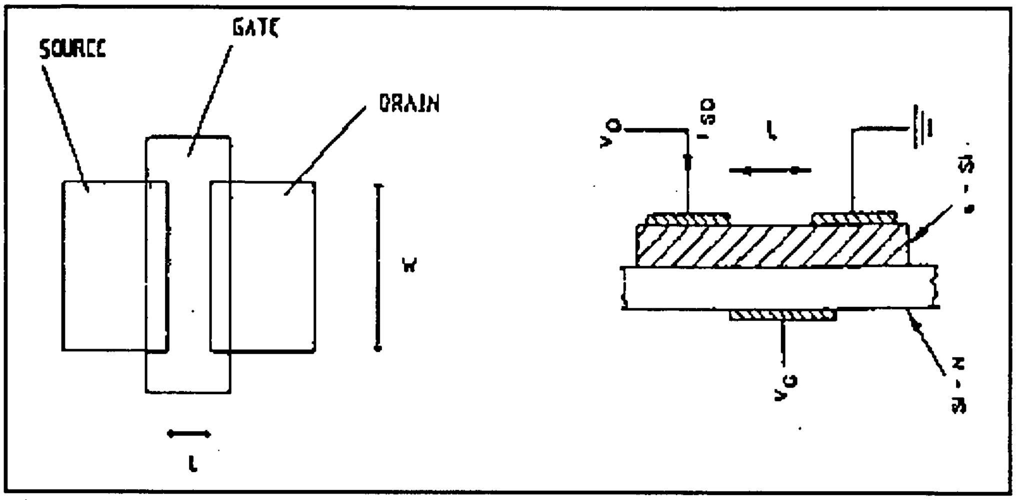


Figure 3.3. Schematics of a thin-film transistor.

Figure 3.4 shows the characteristics of an optimized amorphous silicon TFT. The on current and off current are in the microampere and picoampere range, respectively, as required. Amorphous silicon has been most successful for high resolution large area displays because of its low dark conductivity and relatively easy fabrication on large area glass substrates. Amorphous silicon TFTs with three different structures are used (Figure 3.5) (Onona 1989). In all structures the gate insulator (often SiN_x, a-Si and a-Si n+ (phosphorous doped a-Si) are deposited by plasma-enhanced chemical vapor deposition (PECVD). The n+ layer provides a low resistance ohmic contact for source and drain, and suppresses hole injection at negative gate voltage. In the usual inverted staggered structure after the patterning of the source and drain metal, the n+ layer in the channel is etched and a passivation layer is deposited to protect the channel (back- channel-etched). In the trilayer type inverted staggered TFT, the active semiconductor layer is protected by being sandwiched between two insulators. Furthermore, in this configuration, the a-Si can be made thinner in order to reduce light sensitivity.

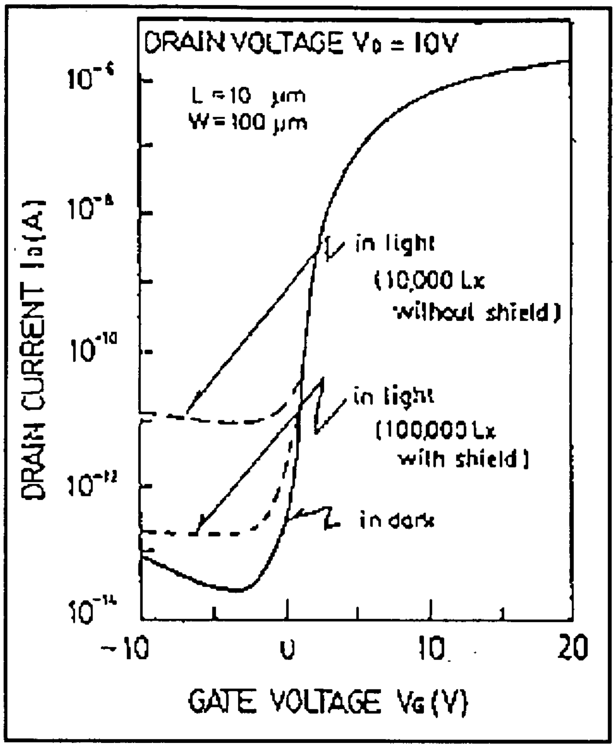


Figure 3.4. Characteristics of a-Si TFTs.

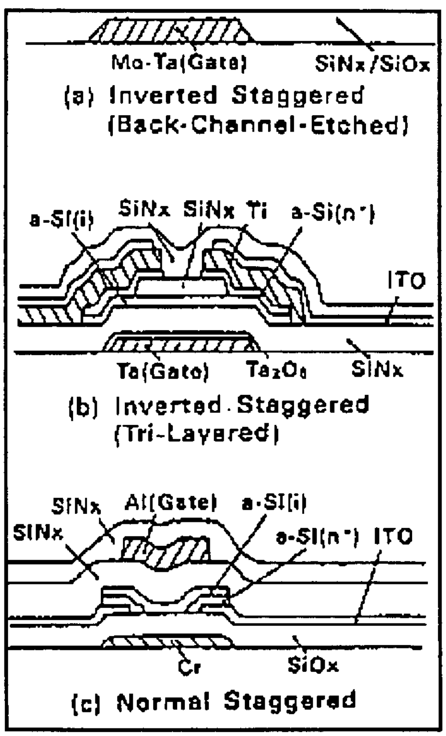


Figure 3.5. Cross sections of a-Si TFTs.

In the normal, staggered type of TFT, the light sensitivity problem is solved with the help of a light shield layer that is deposited and delineated first. Source and drain metals are then

deposited and patterned, followed by the deposition and patterning of a-Si and gate insulator. The gate metal is deposited and patterned on top.

In all three processes an additional deposition and patterning step is usually necessary for the ITO pixel electrode. Metals such as Ta, Cr, MoTa and Al are used for the gates and select lines. Ta and MoTa can be anodically oxidized to provide an extra gate insulator, which virtually eliminates the occurrence of crossover shorts between select and video lines (Katayama et al. 1988). For source, drain, and video lines, Ti, Mo, Al, or Al/Cr are frequently employed.

Amorphous silicon TFTs have a field-effect mobility of 0.3-1 $c^2/(V\text{-sec})$ and a threshold voltage V_{th} of about 2 V.

The mobility of p-Si TFTs is much higher, around 50 $c^2/(V\text{-sec})$. P-Si TFTs usually have a top-gate configuration and can be fabricated in a low-temperature (600 degrees centigrade) process on hard glass substrates or in a high-temperature process (1,000 degrees centigrade) on quartz substrates.

In Figure 3.6, an example of a low- temperature p-Si TFT fabrication process is shown (Morozumi 1986). First a 1,500 phosphorus doped p-Si layer is deposited on a hard glass substrate and patterned as source-drain electrodes. Then a very thin layer (typically 250) of undoped p-Si is deposited by low-pressure chemical vapor deposition at 600 degrees centigrade and patterned. An ITO film is then deposited and patterned into data lines and pixel electrodes. The gate insulator of 1,500 thick SiO_2 is deposited by thermal CVD. Finally, the Cr gate electrodes are sputtered and delineated. For the high-temperature p-Si TFT, the gate insulator is thermally grown at about 1,000 degrees centigrade, and source-drain doping is accomplished by ion implantation. Figure 3.7 shows the characteristics of a typical low-temperature p-Si TFT (Morozumi 1986).

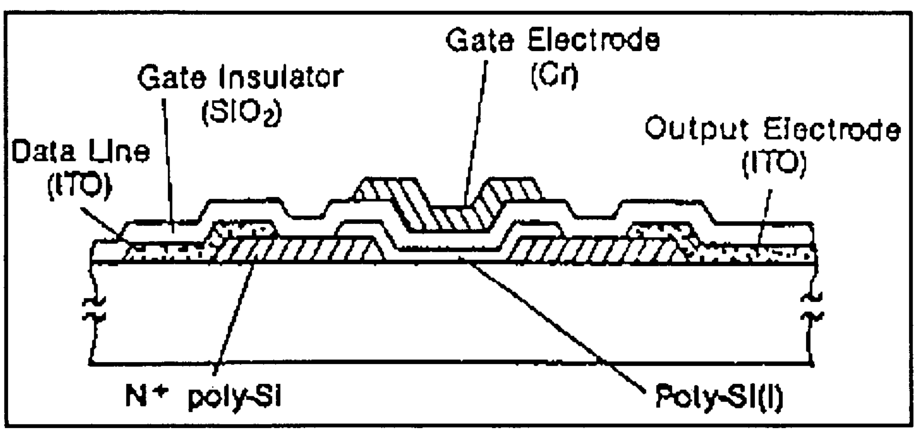


Figure 3.6. Cross section of low-temperature p-Si TFT.

One of the major advantages of p-Si TFTs is their potential for integrated row and column driver circuits, which can significantly reduce the number of interconnections from the display substrate to the external electronics. For interlaced TV operation, the row drivers have to

operate at 16 kHz, which requires a TFT mobility of about 0.5 c^2/(V-sec). This can be achieved with both a-Si and p-Si TFTs. For the column drivers, however, the operating frequency has to exceed 8 MHz for monochrome and 23 MHz for color panels. A minimum mobility of 10 c^2/(V-sec) is required, which excludes a-Si. A cross sectional view of a TFT LCD is shown in Figure 3.8

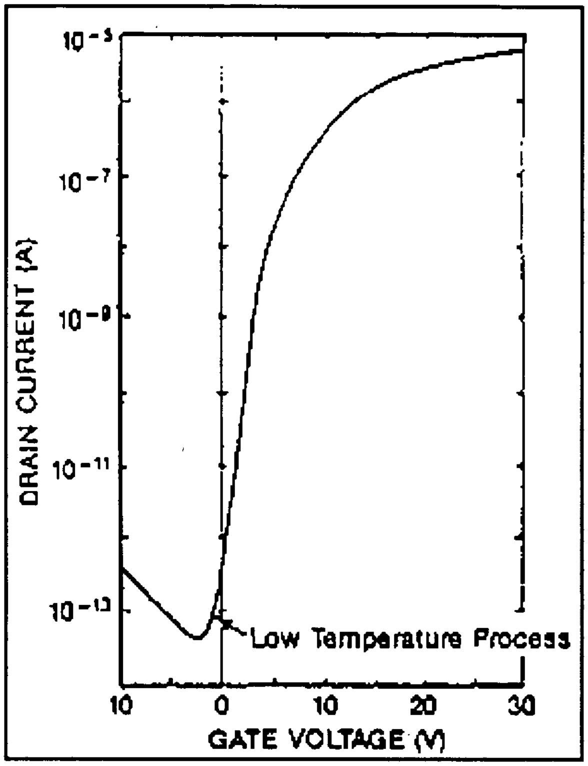


Figure 3.7. Characteristics of low-temperature p-Si TFTs.

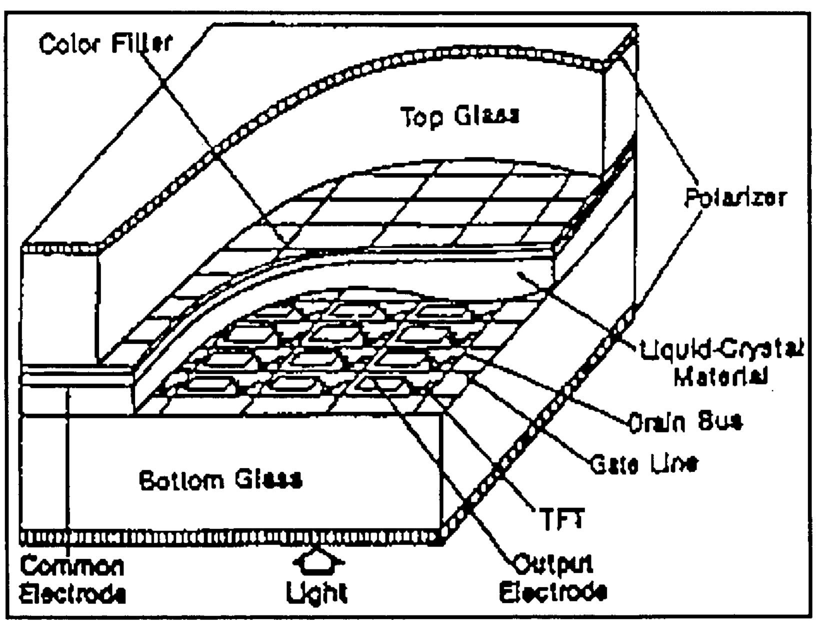


Figure 3.8. Cross-sectional view of TFT LCD.

For color displays, red, green, and blue color filters are patterned on the top plate. In the interpixel area on the top plate, an opaque material is deposited and patterned. This black matrix improves the contrast ratio by preventing light leakage in the areas between the pixels.

MIM Diode Displays. Baraff et al. (1981) proposed to use MIM diodes as the pixel switches in active matrix LCDs. The current voltage characteristics of MIM diodes used in LCDs usually obey the Poole-Frenkel equation (Frenkel 1938), that is:

I = kV exp (bþV)

where *I* is the current, *V* is the applied voltage, and *k* and *b* are constants.

MIM diodes are bidirectional switches and have approximately symmetrical current-voltage characteristics. Diodes of Ta_2O_5 are relatively easy to fabricate. Films of Ta are first sputtered. After patterning, the tantalum is anodized in a dilute electrolyte such as citric acid, phosphoric acid, or ammonium tartrate. During the anodic oxidation, part of the Ta film is converted into Ta_2O_5. For an anodizing voltage between 20 V and 50 V, a thickness of 30-700 is obtained that is suitable for application in LCDs.

The anodic oxidation process produces excellent film uniformity that is virtually pinhole free.

The metal for the counterelectrode on top of the Ta_2O_5 is selected to obtain symmetric current voltage characteristics (Morita et al. 1990). Titanium, chromium, and aluminum give good results, whereas molybdenum and indium tin oxide produce asymmetric curves with partially rectifying behavior.

The nonlinearity factor *b* (÷4 for Ta_2O_5 can be improved using alternative insulators. One of them is off-stoichiometric silicon nitride (SiN_x produced by PECVD (Suzuki 1986). The I-V characteristics of SiNx diodes can also be fitted to the Poole-Frenkel equation. The factor *b* increases with increasing nitrogen content in the film and ranges from 4.5 to 6, significantly higher than for Ta_2O_5 MIM diodes. Figure 3.9 shows the I-V characteristics of a typical SiN_x and Ta_2O_5 MIM.

In a diode active matrix display, rows and columns are usually on opposite glass substrates, eliminating the possibility of crossover shorts. This is illustrated in Figure 3.10. The select waveforms are applied to the rows, and the data voltages are applied to the columns. The diodes can be connected either to the row lines or to the column lines. The diode has a parasitic capacitance, and since diode and LC capacitance are in series, any voltage change on the columns or rows will be partially absorbed by the LC capacitance (Figure 3.10). This capacitive charge transfer depends on the ratio of device capacitance to LC capacitance. To reduce cross talk from the column lines, it is important to keep this ratio small.

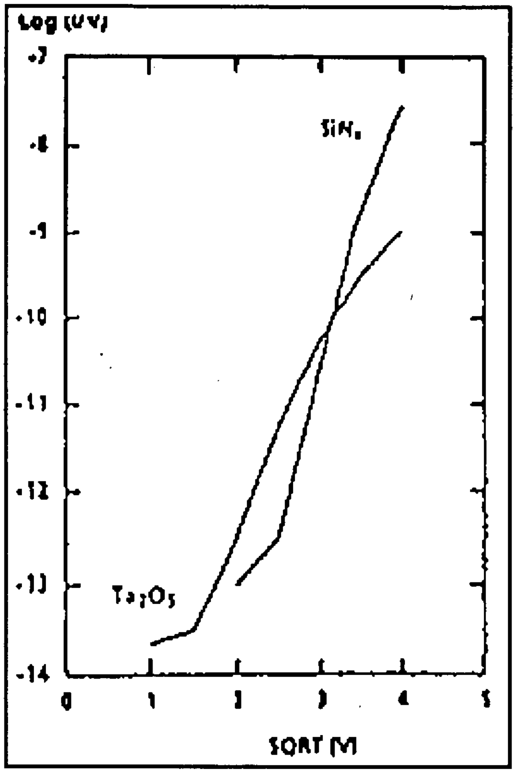


Figure 3.9. Current voltage characteristics of SiN_x and Ta_2O_5 MIMs.

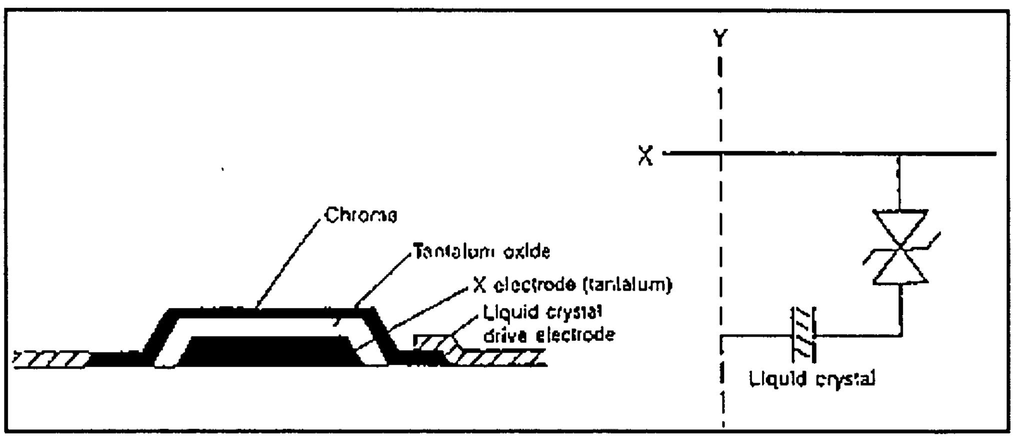


Figure 3.10. Circuit diagram of a pixel and the MIM structure in a MIM diode display.

Since Ta_2O_5 has a high dielectric constant of 22-25, the MIM device area has to be kept small to satisfy the condition $C_{diode}/C_{lc} < 0.1$. Photolithographic limitations on large area substrates, however, make it difficult to reduce their size to less than 4 x 4 þ(meters squared). To circumvent this problem, attempts have been made to fabricate lateral MIM devices, in which the sidewall of the Ta pattern is used for the device (Morozumi 1983) and the device capacitance can be smaller. SiN_x MIMs (Suzuki 1986) share the advantage of a lower dielectric constant (approx. 7), and the device capacitance is a less significant problem than in Ta_2O_5 MIM LCDs.

Pin Diode Displays. Amorphous silicon *pin* diodes are fabricated by PECVD with silane (SiH_4) as a precursor for the undoped i layer (intrinsic) and mixtures of SiH_4 and B_2H_6 or PH_3 for p-type and n-type layers, respectively. To avoid cross- contamination of doped and undoped layers, the films are deposited in a multichamber system with separate chambers for p, i, and n layers. The i layer has a thickness of 2,000-6,000 , and the doped layers are about 500 thick.

Figure 3.11shows the current voltage characteristic of a typical optimized pin diode with an area of 20 x 20 þ(meters squared) (Yaniv 1986a). The ratio between forward and reverse currents at +3 V and -3 V exceeds 8 orders of magnitude. The forward curve up to +1 V is described by the usual diode equation:

$$I = I_0 [\exp(qV/nkT)-1]$$

where I_o is the saturation current and n is the ideality factor. For optimized diodes, the saturation current density is 10^{-13}-10^{-11} A/c(meters squared) and n is 1.3-1.5.

At reverse bias the current is very low, since the p and n layers effectively block the injection of electrons and holes from the contacts and the i layer is depleted of charge carriers. At high reverse bias, around 20 V, the current can increase sharply and soft breakdown occurs. This soft breakdown is reversible, and the voltage at which it takes place depends on i layer thickness and other deposition parameters.

The a-Si diode has asymmetric current voltage characteristics with rectifying behavior. A single diode per pixel is therefore not compatible with the ac drive of LCDs. Any AMLCD with pin or Schottky diodes requires at least two devices per pixel. When two diodes are used in the back-to-back configuration of Figure 3.12, the soft breakdown of the diodes can be used to obtain a symmetric switch with current voltage curve very similar to that of MIM diodes. Since uniformity and reproducibility of soft breakdown are poor, displays based on this approach have not been successful.

By connecting two diodes in an antiparallel fashion (Figure 3.12, a symmetric nonlinear device is obtained. This diode ring configuration has been applied by several organizations (Togashi et al. 1985; Urabe 1989).

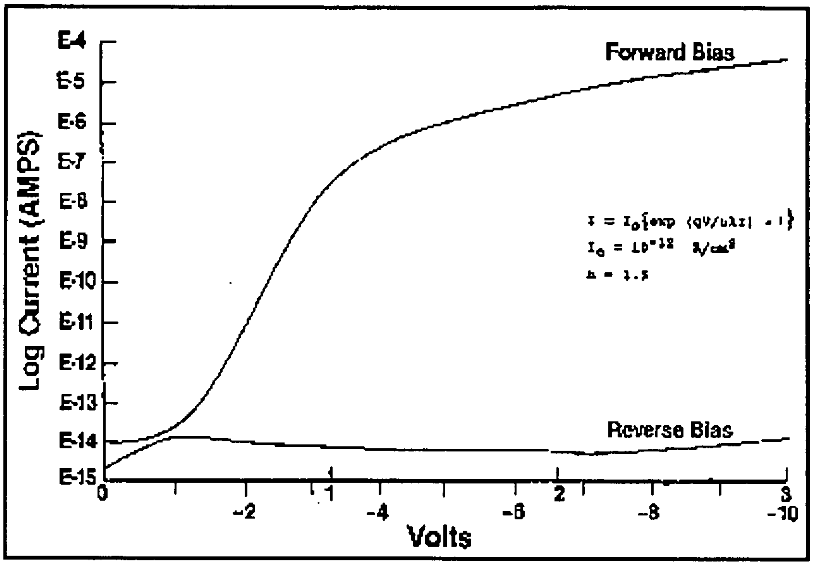


Figure 3.11. Current voltage characteristic of 20 þm pin diode.

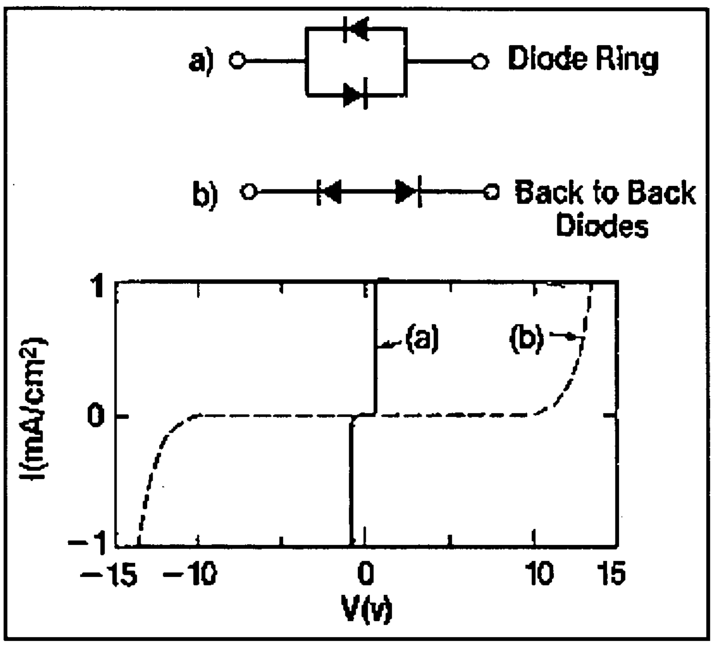


Figure 3.12. Diode ring (a) and back-to-back diode (b) configurations.

The *I*-V characteristic of the diode ring has a low threshold voltage of about 1 V, incompatible with the higher threshold voltage of the TN LC cell of 2-3 V. To suppress leakage through the switch during the holding period, a holding voltage, sometimes also employed in MIM diode displays, is essential for the select line driving waveform in diode ring displays.

The diode ring configuration utilizes only the forward characteristics of the diodes, and hence does not take full advantage of the high on/off current ratio of a-Si pin diodes. A configuration that uses both forward and reverse characteristics (Yaniv et al. 1986b, 1988) is the two-diode switch, depicted in the circuit diagram of Figure 3.13. Each pixel has two diodes, which are

connected to different select lines. The anodes of diodes D_1 are connected to the select lines S^2, and the cathodes of diodes D_2 are connected to select lines S_2. One of the driving methods is shown in Figure 3.13.

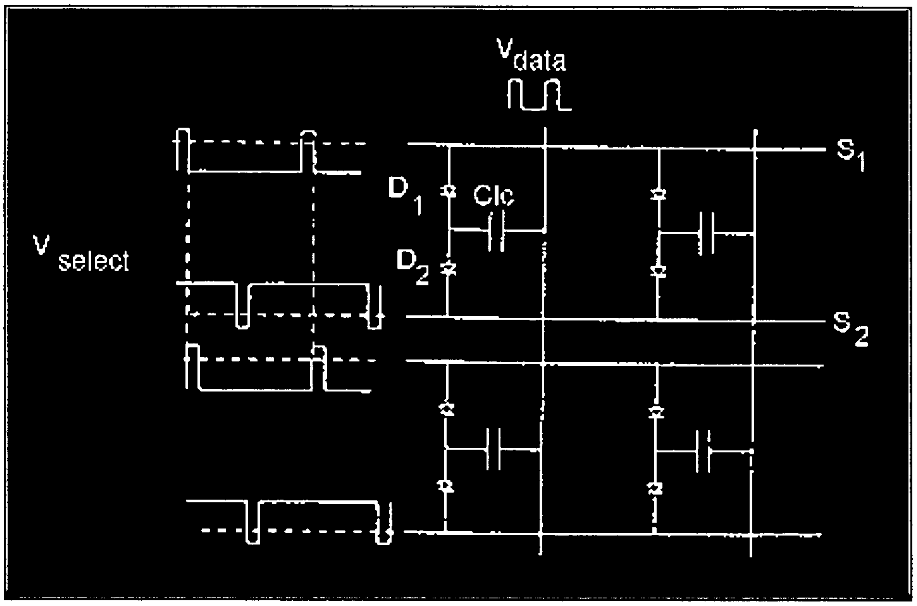


Figure 3.13. Two-diode switch configuration operated in the alternate scan mode.

For the purpose of device redundancy, two or three diodes can be connected in series in each branch (Yaniv 1988). When one diode is short-circuited, the other two diodes in the branch will prevent the occurrence of a pixel defect. The increased number of diodes per branch has the added benefit of reducing the effective overall device capacitance and of reducing the maximum reverse bias per diode. As mentioned before, a-Si pin diodes can suffer from soft breakdown at high reverse bias. The series connection of three diodes virtually eliminates this effect.

The two-diode switch approach requires two select lines for each row of pixels and therefore doubles the number of interconnections and driver circuits for rows. The D^2R (double diode plus reset) circuit proposed by Philips (Kuijk 1990) does not suffer from this drawback.

Arrays of pin diodes for displays require three to four photolithography steps. The processes for diode ring, back-to- back diodes, or two-diode switch displays can be basically the same. In one commonly used process, the ITO layer is patterned first, followed by deposition of the sandwich Cr-pin-Cr (Figure 3.14). The top Cr is patterned and used as a mask to etch the a-Si layer in a dry etching process. The bottom metal is then patterned. A silicon nitride layer is deposited, and contact holes are opened on top of the diodes. Finally, a top metal such as Al, Mo, or Ni is deposited to connect the diodes and to form the bus lines. The bus lines consist of a double metal layer of the bottom metal and the top metal. This line redundancy increases the yield. The diodes are shielded from light because they are completely encapsulated by the metal electrodes.

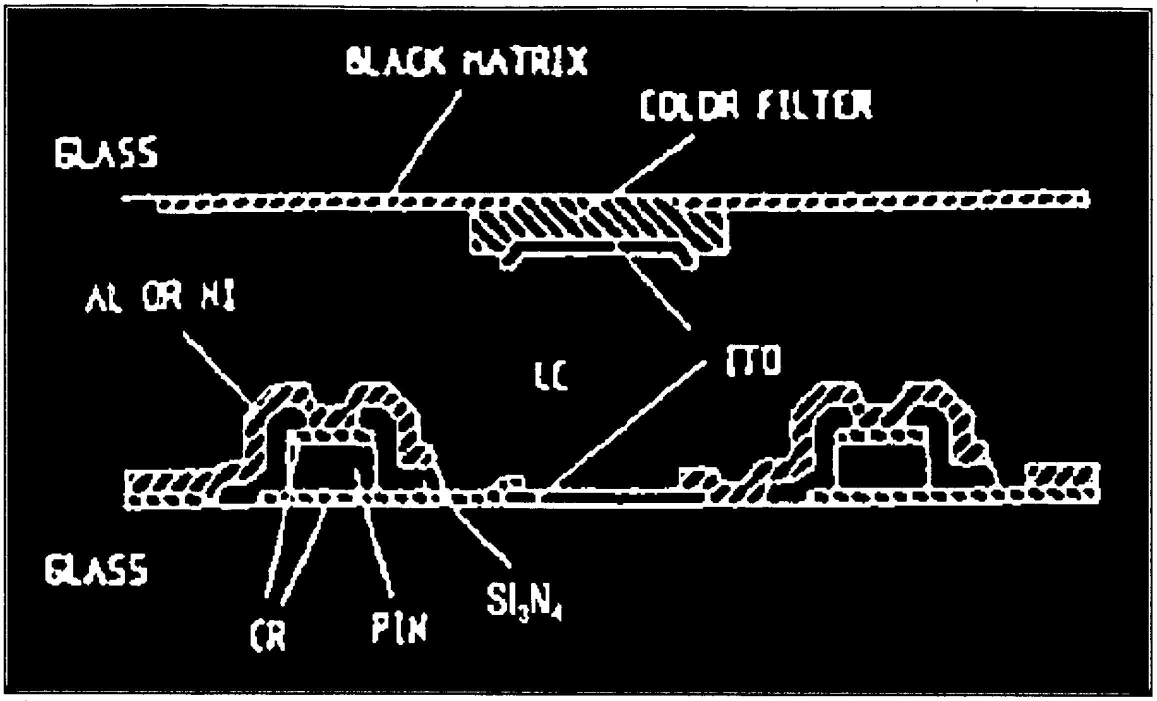
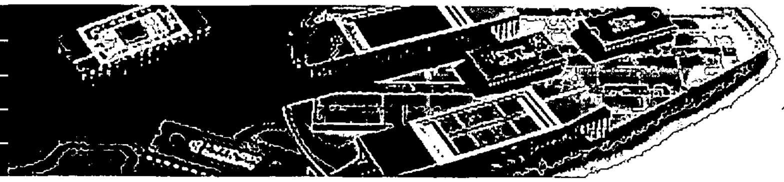


Figure 3.14. Cross section of pin diode display.

Published: December 1994; *WTEC Hyper-Librarian*



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TFT LCD news
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TFT LCD manufacturing
what is TFT LCD
electronic aspects
fabricating TFT LCD
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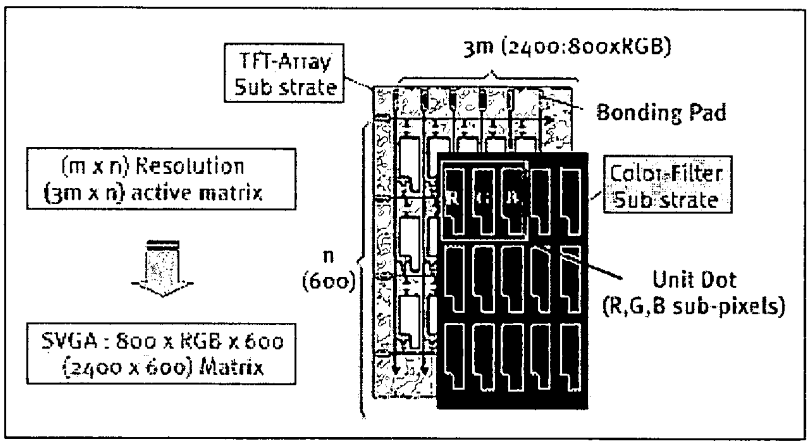
How TFT LCD Pixels Work

A TFT LCD panel contains a specific number of unit pixels often called subpixels.
Each unit pixel has a TFT, a pixel electrode (ITO), and a storage capacitor (C_S).
For example, an SVGA color TFT LCD panel has total of 800x3x600, or 1,440,000, unit pixels.
Each unit pixel is connected to one of the gate bus-lines and one of the data bus-lines in a 3mxn matri format. The matrix is 2400x600 for SVGA.

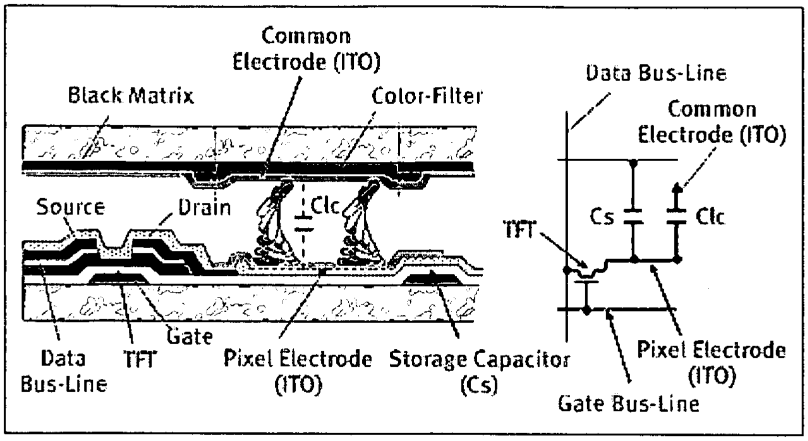
Structure of a color TFT panel.



Because each unit pixel is connected through the matrix, each is individually addressable from the bonding pads at the ends of the rows and columns.
The performance of the TFT LCD is related to the design parameters of the unit pixel, i.e., the channel width W and the channel length L of the TFT, the overlap between TFT electrodes, the sizes of the storage capacitor and pixel electrode, and the space between these elements.
The design parameters associated with the black matrix, the bus-lines, and the routing of the bus line: also set very important performance limits on the LCD.

In a TFT LCD's unit pixel, the liquid crystal layer on the ITO pixel electrode forms a capacitor whose counter electrode is the common electrode on the color-filter substrate.

Vertical structure of a unit pixel and its equivalent circuit Top

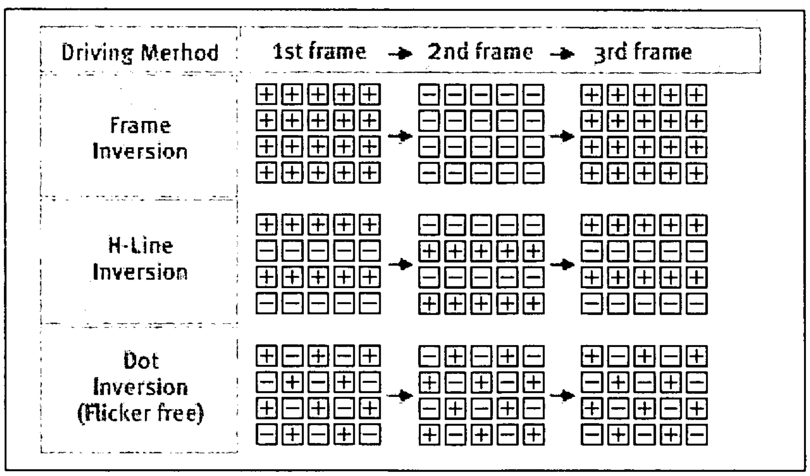


A storage capacitor (C_S) and liquid-crystal capacitor (C_{LC}) are connected as a load on the TFT. Applying a positive pulse of about 20V peak-to-peak to a gate electrode through a gate bus-line turns the TFT on. Clc and Cs are charged and the voltage level on the pixel electrode rises to the signal voltage level (+8 V) applied to the data bus-line.

The voltage on the pixel electrode is subjected to a level shift of DV resulting from a parasitic capacitance between the gate and drain electrodes when the gate voltage turns from the ON to OFF state. After the level shift, this charged state can be maintained as the gate voltage goes to -5 V, at which time the TFT turns off. The main function of the C_S is to maintain the voltage on the pixel electrode until the next signal voltage is applied.

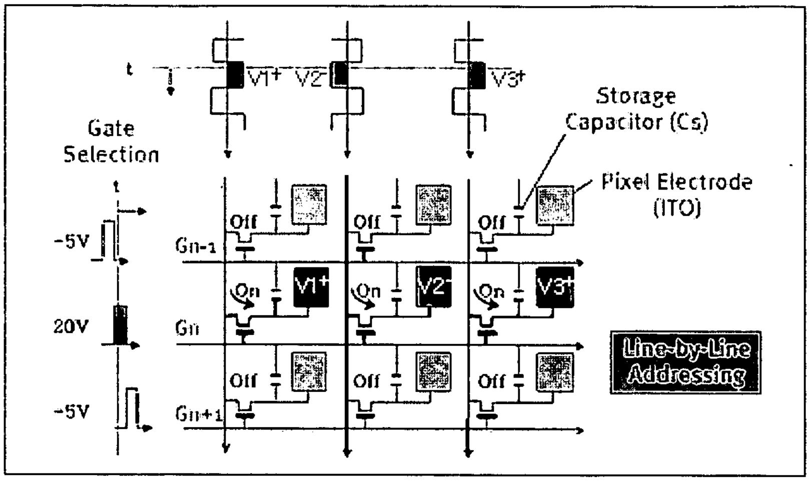
Liquid crystal must be driven with an alternating current to prevent any deterioration of image quality resulting from dc stress.
This is usually implemented with a frame-reversal drive method, in which the voltage applied to each pixel varies from frame to frame. If the LC voltage changes unevenly between frames, the result woul be a 30-Hz flicker.
(One frame period is normally 1/60 of a second.) Other drive methods are available that prevent this flicker problem.

Polarity-inversion driving methods. Top



In an active-matrix panel, the gate and source electrodes are used on a shared basis, but each unit pixel is individually addressable by selecting the appropriate two contact pads at the ends of the rows and columns.

Active addressing of a 3x3 matrix Top



By scanning the gate bus-lines sequentially, and by applying signal voltages to all source bus-lines in a specified sequence, we can address all pixels. One result of all this is that the addressing of an AMLCD done line by line.

Virtually all AMLCDs are designed to produce gray levels - intermediate brightness levels between the brightest white and the darkest black a unit pixel can generate. There can be either a discrete number of levels - such as 8, 16, 64, or 256 - or a continuous gradation of levels, depending on the LDI.

The optical transmittance of a TN-mode LC changes continuously as a function of the applied voltage. An analog LDI is capable of producing a continuous voltage signal so that a continuous range of gray levels can be displayed.
The digital LDI produces discrete voltage amplitudes, which permits on a discrete numbers of shades t be displayed. The number of gray levels is determined by the number of data bits produced by the digital driver.

ILA®/D-ILA™ Super Projectors for the Present and the Future

Mitsuru Hayakawa
Victor Company of Japan, Limited (JVC)

Introduction

Projectors are now an essential component in display systems for applications requiring a large screen image that provides an image so real, the viewer feels as if he is watching a live performance, while conveying vital information with sales appeal. On the one hand, the projection device, a key enabling component of the projector, requires resistance to light and heat since high intensity light rays are concentrated on the small device area, while at the same time high precision processing is required to achieve high resolution. Currently, many technological developments are advancing worldwide in an effort to create even higher performance projectors.

This paper describes the configuration and performance of unique spatial light modulators (SLM), the Image Light Amplifier (ILA®) and the Direct-drive Image Light Amplifier (D-ILA™) devices, and projectors incorporating them. It also discusses the future outlook for D-ILA™ devices.

Market Introduction of ILA® Projectors

In the early 1970s, Hughes Aircraft Company performed research in the U.S. on light addressed spatial modulators, and by the end of the 1980s it had established its projector technology for moving pictures.[1]

Meanwhile, Victor Company of Japan, Limited (JVC) conducted its own research and development of light addressed spatial light modulators viewing them as the optimal projection system for the coming age of large screen displays. These two companies that were developing common projection technologies established Hughes-JVC Technology Corporation, and began selling ILA® Super Projectors[2,3,4] in 1993. By the late 1990s the marketplace recognized these projectors as the principal projection method for large screen projection.

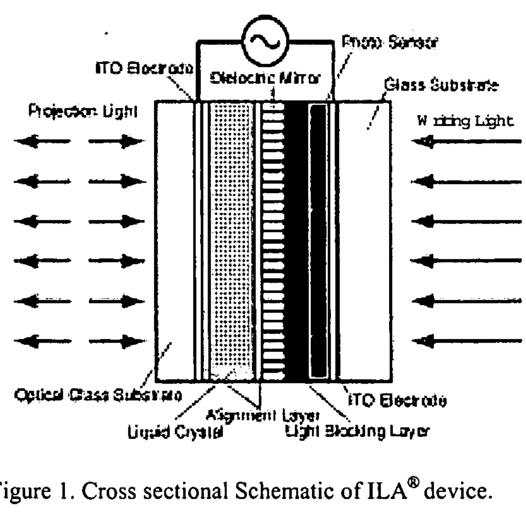


Figure 1. Cross sectional Schematic of ILA® device.

Configuration and Operation of the ILA® Device[1]

As shown in Figure 1, the ILA® device is configured by several layers of thin film sandwiched between two glass substrates. There are four principal thin film layers: a photosensor layer, a light-blocking layer, a dielectric mirror, and a liquid crystal layer. A characteristic of this configuration is that it creates an image without pixel artifacts. Figure 2 shows the basic design concept of the ILA® projector. The input image is provided by a CRT. The two-dimensional CRT writing light image is focused on the amorphous silicon (a-Si) photosensor. Since the impedance of the photosensor changes depending on the writing light intensity, the voltage pattern on the liquid crystal layer also changes. In the output projection, the light beam from the lamp passes through the polarizing beam splitter (PBS) and light in the S-polarization state enters the liquid crystal layer. Consequently, light modulation of the projection beam takes place and the returning P-polarization state output light travels through the PBS, and the projection lens focuses and magnifies the image onto a screen.

Features and Issues of the ILA® Projector

The ILA® Projector incorporates a system that enabled for the first time simultaneous achievement of the seemingly conflicting requirements of high brightness and high resolution. The features of this projector are listed below:

① The projection light that determines light output is reflected from the dielectric mirror that has 100% aperture ratio, thereby enabling the projection of high bright images without any light loss.

② The writing light that determines resolution is a low-intensity beam, therefore the CRT beam current is low, easily allowing for the achievement of high resolution images.

③ High contrast was achieved by successfully mass-producing for the first time, devices with homeotropic liquid crystal alignment which was said to be difficult to do.

④ Image reproduction without distortion is possible since there are no pixel artifacts, and no false signals are generated in response to the various input signals.

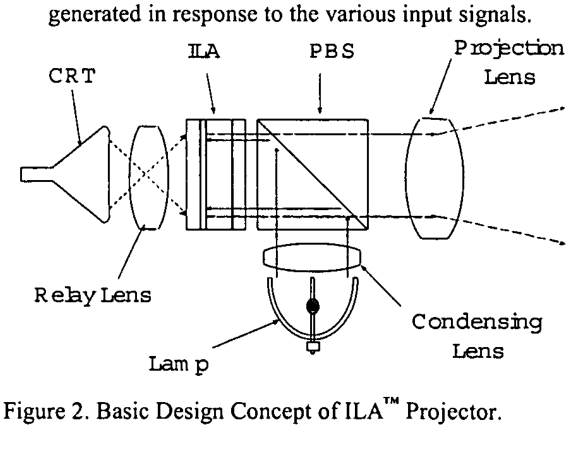


Figure 2. Basic Design Concept of ILA™ Projector.

While the ILA® Projector has proven its high performance capabilities by achieving a light output of 12,000 lumens, a limiting resolution of 1600 TV lines and a contrast ratio greater than 1000:1, some of its issues are listed below:

① As long as the ILA® is used for projection, and the CRT is used for device addressing, there is a need to have two key components in the projector. Consequently, size and weight inevitably grow, which in turn makes cost an issue.

② Since the writing light image is generated by the CRT's finite electron beam, the modulation transfer function (MTF) is that of a Gaussian shaped beam intensity profile. Consequently, the limiting resolution is extremely high which is perfect for image display, however legibility of small text becomes an issue.

Development of the D-ILA™ Projector

In recent years, the availability of high-speed, high capacity computers at a low cost has made the use of graphics and text in presentations commonplace. As a result of this trend, there has been a strong demand for improvements in text legibility.

In order to solve the issues of the ILA® Projector described above while maintaining its features, JVC independently developed the new D-ILA™ device that allows for direct projection of picture signals onto pixels. Believing it important to develop this new projection method to meet future market demands making it the mainstream technology in the 21st century, JVC launched the D-ILA™ Multi-Projector with SXGA resolution at the beginning of 1998.

Configuration and Operation of the D-ILA™ Device[5,6]

The liquid crystal on silicon (LCOS) configuration of the D-ILA™ device is shown in Figure 3. Using the CMOS process, the X-Y matrix for pixel address selection and the aluminum reflective electrode corresponding to each pixel are formed on the silicon substrate, and after the surface flattening process, the alignment layer is applied. The glass substrate has a transparent electrode and an alignment layer on it. The liquid crystal with homeotropic alignment is sandwiched between the silicon substrate and the glass substrate.

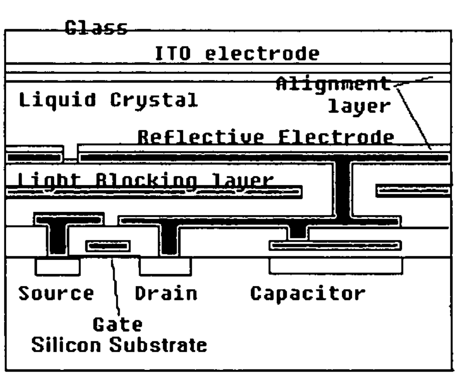


Figure 3. Cross-section view of D-ILA™ device.

The basic operation of the D-ILA™ projector is shown in Figure 4. As with the ILA® Projector, the light from the lamp travels through the PBS with the S-polarization state entering the D-ILA™ device. The incident light goes through the liquid crystal layer and is reflected back to the PBS by the pixel electrodes. At this time, in the activated pixels, the polarization direction of light in the S-polarization state is rotated in response to image modulation of the liquid crystal layer converting it to the P-polarization state, and this light goes through the PBS and projection lens, and is projected on the screen. The non-activated pixels produce no modulation of the liquid crystal layer, so the light in the S-polarization state is reflected by the PBS and returned to the lamp, thus becoming the black level.

Features of the D-ILA™ Device

① The LCOS structure of the D-ILA™ device induces a high aperture ratio of 93% because of the three-dimensional configuration of pixel address selection behind the light modulating liquid crystal layer. Thus, the entire device area can be used for reflection, excluding the insulation between the pixel electrodes.

② The high aperture ratio means that there are few instances of device thermal instability resulting from light to heat conversion, and error of the driving device due to light to signal conversion, making it simple to achieve high light output that can withstand high intensity light input.

③ The CMOS process enables a small pixel pitch so that 13.5 µm pitch on a 0.9" panel achieves SXGA (1365 x 1024) resolution. Further reduction in pixel pitch will enable higher resolutions, and of all current projection devices, the D-ILA™ has the greatest potential for higher density pixel structures.

④ This device is based on the proven performance of the homeotropically aligned liquid crystal of the ILA® device, and it can easily provide high contrast images. The device alone is capable of a contrast ratio greater than 1000:1.

⑤ A characteristic of reflective type devices is that modulation takes place while the light is passing in and out of the liquid crystal layer, allowing for half the cell gap of a transmissive type device, enabling this device to have a fast response time of less than 16 milliseconds.

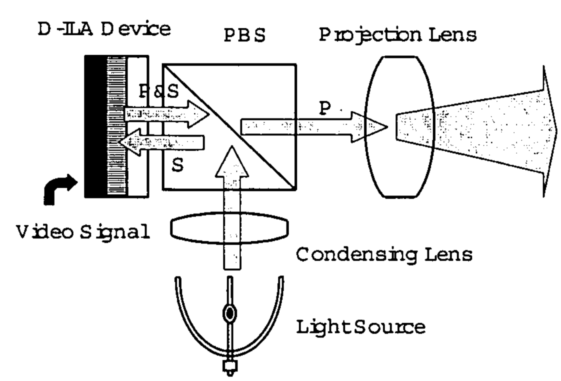


Figure 4. Basic Design Concept of D-ILA™ Projector.

Basic Configuration of the D-ILA™ Projector

Figure 5 shows the configuration for a three-panel D-ILA™ system. A large portion of the unpolarized light from the lamp is converted to the S-polarization state by passing through the PS Combiner (PSC), comprised of two fly-eye plates and a PBS plate, which simultaneously increases the light collection efficiency and improves light uniformity across the optical path plane. The light is then separated into red, green and blue components by the color separation optics and sent into the PBS corresponding to each color.

The S-polarization state that is reflected by the PBS is modulated by the D-ILA™ device for each color, as previously explained by Figure 4, and only light in the P-polarization state passes through the PBS, where the RGB color components are combined in the cross dichroic prism and a color image is projected through the projection lens onto the screen.

As just explained, the D-ILA™ Projector has successfully maintained the features of high brightness, high resolution and high contrast ratio of the existing ILA® Projector by changing the addressing system from an optical image to an electronic signal to directly drive the device. At the same time, this new technology has solved the ILA® Projector issues of size, weight, cost and text legibility.

Light output of the first D-ILA™ Projectors[7,8] was 1000 lumens, however, light output of the current product lineup ranges from 1500 lumens to 4000 lumens. Together with high brightness and high resolution, these projectors have been recognized for their outstanding color reproduction enabled by the use of a xenon lamp, thus establishing the D-ILA™ Projectors as a high quality image projector.

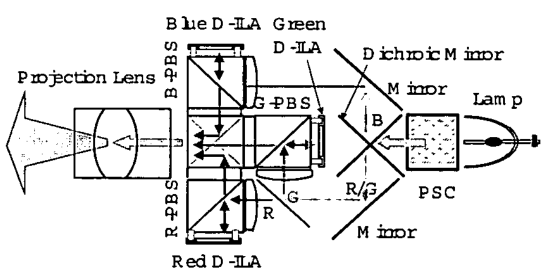


Figure 5. Optical system of D-ILA™ Projector.

D-ILA™ Application for Single Color Panel with Hologram

The three panel system, which is the basic configuration of the projector, is suitable for professional use because of the high light collection efficiency, and the device characteristics directly translates to projector performance. However, in the consumer market where business is dictated by low prices, there has been a strong call to make the projector more compact and affordable by having fewer panels or changing the optical system. Thus a single panel system is desirable.

There are two types of single panel systems: the field sequential system where color multiplexing is done temporally, and the simultaneous spatial multiplexing, where color multiplexing is done spatially.
The field sequential method, has the benefit of projecting the device's true resolution by sequentially switching between the RGB light components in synch with the field frequency. However, this requires three times more field drive frequency. In addition, other problems could arise more easily such as color break-up resulting from false signals due to a time differential, and color contamination and field flicker due to the driving conditions.

The spatial multiplexing method, on the other hand, separates the pixels on the single panel into red, green and blue, thereby avoiding the problems of color break-up, color contamination and flickering. While this method yields image quality similar to the three-panel system, a high pixel density single panel is essential since three times the number of pixels is required to produce the necessary resolution.

A common issue for both methods is the theoretical problem that simple color multiplexing causes a 1/3 reduction in the light collection efficiency.

In the D-ILA™ single color panel projector, the D-ILA™ device's high pixel density characteristics are utilized in combination with a hologram color filter (HCF), producing the new D-ILA™ Hologram Device that minimizes the reduction in light collection efficiency. A consumer projection television incorporating this new device has been in the market since the end of 1999.

Configuration and Theory of the D-ILA™ Hologram Device

Figure 6 shows the configuration and theory of color multiplexing of the D-ILA™ Hologram Device. Pixel electrodes are formed on a CMOS silicon substrate, and the basic configuration is the same as the D-ILA™ device with the alignment layer, liquid crystal layer, alignment layer and transparent electrode; however, by placing the HCF on top of the transparent electrode layer, the RGB sequential sub-pixels that correspond to each white pixel are formed. The incident white light is diffracted through the hologram filter, and enters at a different angle for maximum light

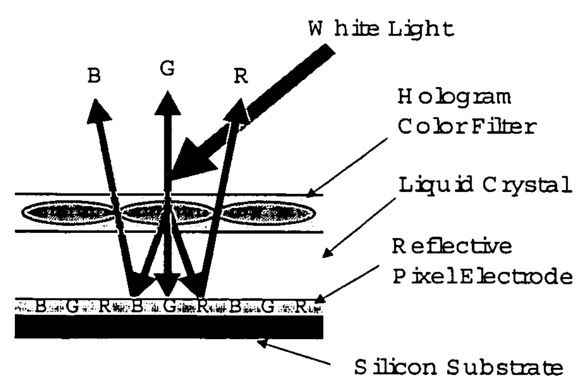


Figure 6. Cross sectional schematic of D-ILA™ Hologram Device.

collection efficiency for each color. Thus, the white light is separated into RGB components depending on optical wavelength, and after passing through the liquid crystal layer the color components will converge onto their respective color pixel electrode. The RGB light is reflected from the pixel electrode, returning through the liquid crystal layer and reaching the HCF. This light enters perpendicular to the HCF, resulting in very little diffraction, and proceeds through the HCF. As explained for the D-ILA™ device, optical modulation takes place in response to the input signal level while the light passes in and out of the liquid crystal layer, and projection light is generated in accordance with that level of modulation.

Creation of a full color image using this hologram device requires three times the number of pixels necessary for a desired resolution, and this was accomplished for the first time by using the high pixel density characteristics possible with the D-ILA™ device.

Configuration of the Signal Panel Projector with D-ILA™ Hologram Device

The conceptual structure of the single panel projector utilizing the D-ILA™ hologram device is shown in Figure 7. The white light from the lamp passes through the cold mirror, and after the condenser lens has collected the

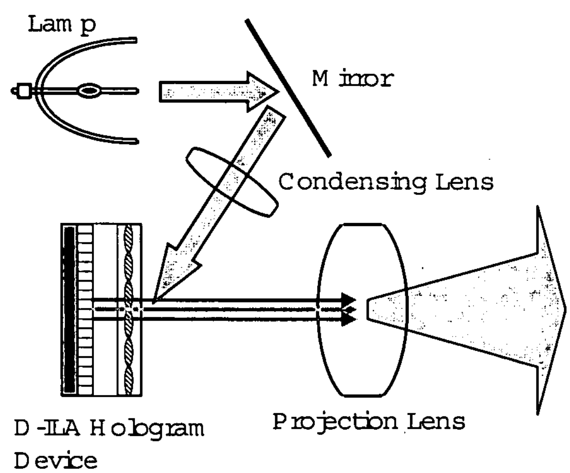


Figure 7. Basic Design Concept of Single D-ILA Projector.

Table 1. Device Specifications

	D-ILA™ SXGA device	D-ILA™ Hologram device
Device size (diag.)	0.907 inches (4:3)	1.22 inches (16:9)
Pixel numbers	1,365(H)×1,024(V)	1,280×3(H) × 1,028(V)
Pixel pitch	13.5um(H)× 13.5um(V)	7um×3(H)× 14.8um(V)
Aperture ratio	93 %	88 %
Contrast ratio	>1,000 : 1	>1,000 : 1
Response time	<16 m sec	<16 m sec

visible light, the light exits the PBS as linearly polarized light and enters the D-ILA™ hologram device at an angle. Only light that has been rotated in response to the level of image modulation of the liquid crystal is projected onto the screen after passing through the projection lens.

Specifications of the current D-ILA™ device and D-ILA™ hologram device are shown in Table 1.
The hologram device has achieved a horizontal pixel pitch of 21÷3=7 μm, thus creating a device with highest pixel density, and achieving an aperture ratio of 88%.

Making full use of the vertical alignment of the liquid crystal, the device by itself can achieve a contrast ratio greater than 1000:1. The projector can also achieve a contrast of 1000:1, although the actual system contrast ratio will depend on the optical system utilized.

Future Evolution of D-ILA™

Since the D-ILA™ device is configured on a silicon substrate through the standard CMOS process, scaling is easily done, and its high flexibility in pixel size makes it suitable for high density pixel structures. Therefore, there is ample room left for development of more compact or higher resolution devices.

The current device size (display area diagonal) is 0.9" for SXGA panel (4:3) and 1.22" for a single panel system (16:9). The pixel pitch is 13.5 μm for the 0.9" device; however, as mentioned earlier the single panel system has achieved 7 μm.

Therefore, it can be said scaling can be done without difficulty when pixel pitch is within the range of 7 μm and 13.5 μm in further development of D-ILA™ device.

Compact Devices

D-ILA™ scaling can be expressed simply as a straight line when the pixel pitch is taken to be the parameter, as shown in Figure 8 where the horizontal axis refers to device size and the vertical axis refers to resolution (number of horizontal pixels). Scaling for an aspect ratio of 4:3 and 16:9 is shown in (A) and (B), respectively.

Current SXGA resolution can easily be achieved with a pixel pitch of approximately 10 μm and device size of 0.7" and experiments have already proven this. If a 7 μm pixel pitch is used, SXGA resolution is possible with a 0.5" device and this has become the goal of future development.

Accordingly, as the devices become smaller, it brings us one step closer to achieving more compact and low cost D-ILA™ projectors while maintaining high resolution.

High Resolution Required for Electronic Cinema

Great advantages in film production, distribution and exhibition can be expected in Electronic Cinema where 35 mm film is digitized and replaced by video signals.

The key technology enabling electronic cinema is the projector, and in order for it to replace the film projector inside movie theaters it must meet some stringent demands with regard to resolution, picture quality and brightness.

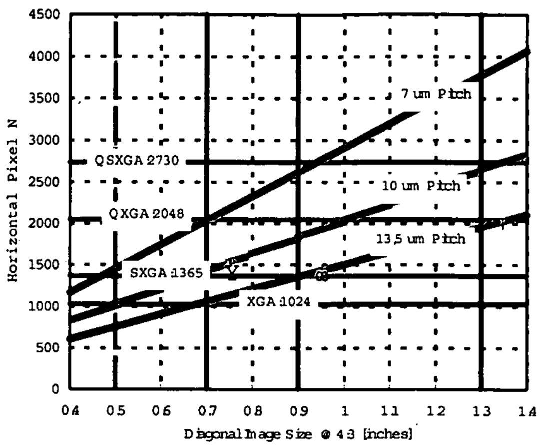


Figure 8. (A) Scaling at 4:3 aspect of D-ILA Device

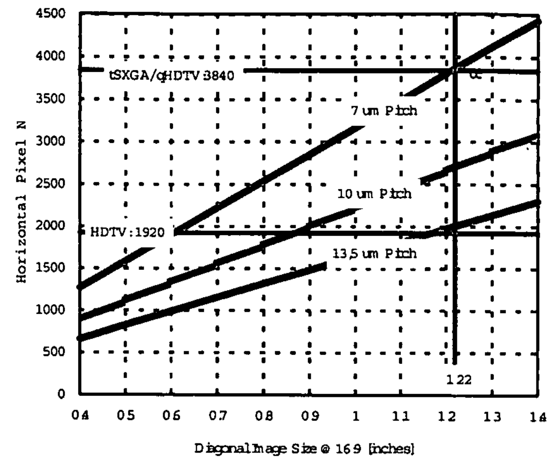


Figure 8. (B) Scaling at 16:9 aspect of D-ILA Device.

In April 1997 at the NAB show, Hughes-JVC Technology, responding to these stringent requirements, demonstrated the ILA-12K projector for electronic cinema. The ILA-12K delivers a maximum of 17,000 lumens, horizontal resolution greater than 2000 TV lines and a contrast ratio exceeding 1500:1. Since this projector is capable of reproducing a film-like non-pixelized image, a feature of the ILA® device, it received unprecedented praise from those involved in the film industry. Since then, this ILA® Projector has been utilized at various events as the standard projector for electronic cinema, and has become the development target for other projector companies.[9]

On the one hand, other companies are experimenting with SXGA (1280 x 1024) panels using anamorphic lenses to enlarge the image for the purpose of achieving simple and easy electronic cinema projectors. In this case, failure to meet the High Definition (HD) full spec (1980 x 1080) resolution, which is said to be the minimum application requirement, is apparent, and even if the projector is tolerated for animation, it is said to be unsatisfactory for displays of actual pictures.

At JVC, the thinking is that the resolution exceeding HD full spec is necessary for the genuine electronic cinema and the development of a 1.3" D-ILA™ device with QXGA (2048 x 1536) resolution is underway and a prototype panel has already been tested.

If this QXGA D-ILA™ device is used, it makes enable HD full spec with a 16:9 aspect ratio without question.
Simultaneously it makes possible electronic cinema with high resolution images exceeding the standard ILA-12K projector if QXGA resolution compressed to 4:3 aspect ratio is addressed and projected on to the screen with anamorphic lens to expand the image.
Then the growth to 1.3" in device size also helps to increase the light collection efficiency from lamp to panel, and this makes it easier to obtain the high brightness necessary in electronic cinema.
If greater importance is attached to a compact and high resolution projector rather than high brightness, then the fact that QXGA resolution is possible with a 0.7" size device can be easily understood from Figure 8 (A).

The Path to Super High Resolution

According to scaling shown in Figure 8 (A), further improvements in high resolution are possible for the D-ILA™. The 1.3" device has the potential to achieve Q-SXGA (2730 x 2048) resolution, which has quadruple the pixel density of 4:3 SXGA (1365 x 1024) resolution, adopting a pixel pitch of under 10 μm at most. When this is applied to 16:9 aspect ratio, it is possible to achieve the ultimate super high resolution of 4000 x 2000.

This is not mere wishful thinking, but as shown in Figure 8 (B), the existing single panel hologram device has 3840 pixels horizontally, thus already achieves twice the HD full spec. Therefore, the device that has quadruple the high pixel density of HD full spec with the tentative name Q-HDTV (3840 x 2160) is within our reach, and it is our next development goal. It is almost impossible for another device with competing technologies to achieve this kind of super high resolution, and only the D-ILA™ device has the prospect of achieving it.

Furthermore, if this super high resolution Q-HDTV is used in electronic cinema, one can expect a totally new dimension in electronic cinema opening up, exceeding the quality of present release print of 35 mm film, as mentioned below.

First of all, twice the sampling for pixels of HD full spec enables to display exceptional images, and theoretically would minimize the sampling phase error and the pixel artifact caused by the pixel structure thereby enabling faithful image reproduction.

While it is said that original 35 mm prints have a horizontal limiting resolution of 2035 TV lines (at MTF 5%)[9] basically requiring a resolution of 4000 x 2000 to display this , actual showing in theater is, however, limited to 1000 TV lines due to the vertical jitter of film moving through the gate. The same applies to the telecine, and here lies the one of the constraints of movie film.

Contrary to film, if electronic cinema utilizes the 3840 x 2160 resolution of Q-HDTV and the complete digital system where digital image capturing without use of film is configured through the entire process from production to

distribution, super high resolution images should be displayed without degradation at all, enabling presentation of wonderful crisp images never seen before on screen.
Therefore it is anticipated that when this happens, the electronic cinema will go beyond movie showings as it stands today, playing a vital role in bringing about the world of virtual reality.

Summary

The D-ILA™ device that incorporates the ILA® technology's homeotropic alignment of liquid crystal, is a reflective mode liquid crystal device with a high aperture ratio. It has the highest pixel density format compared to other devices, and it is a device that produces high contrast while achieving both high resolution and high luminance.

Initial D-ILA™ Projector products started with SXGA resolution, however, on a daily basis the market demands more compact, higher resolution and higher picture quality projectors. In order to meet such market demands, we are currently working to design and fabricate 0.7" panels and new D-ILA™ devices with QXGA resolution.

Furthermore, the D-ILA™ technology has high potential for further development, and it is the only technology that can accommodate resolution requirements of electronic cinema or super high resolution of 4000 x 2000, which will become the standard for next generation large screen displays. Thus, D-ILA™ technology will come the stand for large screen display technology of the 21st century.

References

1. W.P. Bleha "Progress in Liquid Crystal Light Valves" LASER FOCUS/ELECTRO-OPTICS, 2394, Vol.19, No.10 p. 111, Oct.1983
2. S. Nakagaki, W.P. Bleha "ILA Video Projectors" ITE REPORT Vol. 17 No.10 p.11 (Jan.1993)
3. T. Miyoshi "High Brightness, High Definition ILA Projectors" JSAP, OSJ, Gp. of Micro Opt. 1994.10/17 Vol.12 No.3 p.31
4. W.P. Bleha "Image Light Amplifier (ILA) Technology for Large-Screen Projection" SMPTE Journal, Oct. 1997 p.710
5. A. Nakano et al, "Reflective active matrix LCD : D-ILA" Photonics West 98 Projection Display IV Proceedings of SPIE volume 3296.(1998)
6. H. Kurogane et al, "Reflective AMLCD for Projection Displays: D-ILA" SID98 p. 33 (1998)
7. F. Tatsumi et al, "Optical System Using 3 Pieces Of D-ILA Panel Module" IDW'98 p.753 (1998)
8. F. Tatsumi et al, "Optical System For Projection Systems Utilizing D-ILA Panels"
ITE JOURNAL Vol.53 No.8 p. 1122 (1999)
9. R.D. Sterling, W.P. Bleha "Electronic Cinema Using ILA Projector Technology" SID99 DIGEST p.216 (1999)

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3.4.1 Field Emitter Array Image Sensor with HARP Target

Research and development advanced on FEA (Field Emitter Array) image sensors with a HARP target, with the aim of realizing ultrahigh-sensitivity, high picture-quality, compact imaging devices that will be useful in the production of various HDTV programs and future broadcasting services with a strong sense of immediacy.

During fiscal 2002, we increased the pixel number of an FEA image sensor, and pursued drastic performance enhancement for image sensors.

With regard to studies to increase the pixel number, the pixel size was reduced to fabricate a 256×192 pixel prototype sensor (pixel size $90\mu m \times 90\mu m$) , or four times the number of pixels in a conventional sensor (128×96 pixels, pixel size $180\mu m\times 180\mu m$). While the microfabrication of pixels requires suppression of the resolution degradation caused by spreading scanning electron beams, we obtained a high resolution equivalent for the number of pixels in the prototype by means of a closer arrangement of the FEA, mesh electrode, and HARP film, as well as by applying a high voltage to the mesh electrode (figure). In addition, high sensitivity was obtained by use of an $8\mu m$-thick HARP film (charge multiplication factor approx. $60\times$), and a wide dynamic range was realized by high integration of the FEA .

Example output image (256×192 pixels)

Based on findings during design and test manufacturing processes of this image sensor, the development of a QVGA FEA image sensor was also initiated, starting with the design of a new FEA with 320×240 pixels and its IC driver chip.

Regarding element technology research for drastic performance improvements in image sensors, we continued with the development work on a high-efficiency FEA and parallel scanning technology. Research on the former included the fabrication of the porous insulating film that will become the foundation of a super-micro, ultrahigh integration field emitter that capable of being driven at low voltage. Studies on the latter progressed to the point of developing electrode division and fabrication technology to prevent defects from arising in a divided HARP film. This is indispensable for parallel scanning operation, and will provide for highly accurate positioning of the divided HARP film and FEA.

3.4.2 Solid-state HARP Imaging Devices

Aiming to develop a small, lightweight, low-power consumption, and highly-mobile high-sensitivity camera system, studies proceeded on solid-state HARP imaging devices that connect a HARP (high-gain avalanche rushing amorphous photoconductor) photo-conversion film and CMOS readout circuit with micro-bump electrodes.

The method of fabricating such a device by combining these two elements has the advantage of enabling the use of separate optimum manufacturing processes for the devices, but had been troubled by sensitivity fluctuations caused by the nonuniform shape and area of the part where the connection was made. In fiscal 2002, we studied a method for forming a highly accurate Au electrode on a HARP photo-conversion film connected to micro-bump electrodes. This resulted in a significant reduction in sensitivity fluctuations thanks to the improved uniformity of connection (figure 1) obtained by forming pixel electrodes with a newly developed micro pitch superprecise evaporating-mask (10× 10μ m² holes, 15.4μ m pitch).

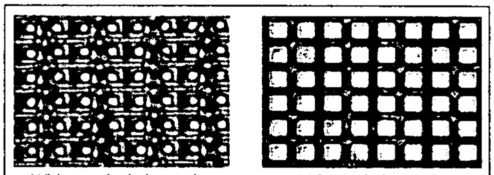


Figure 1: Comparison of contact area between micro-bump electrodes and a HARP film (Infrared microscope image)

To clarify why the operational stability and reliability of solid-state HARP imaging devices vary according to such factors as the pressure on the devices at the time of connection, we studied the sectional view of a joint by means of a special polishing technology. This confirmed that a HARP photo-conversion film in the conventional system without pixel electrodes suffers damage when connected with bump electrodes, and that this problem can be solved by forming pixel electrodes. It was shown that the formation of pixel electrodes on a HARP photo-conversion film is extremely important for the fabrication of solid-state HARP imaging devices.

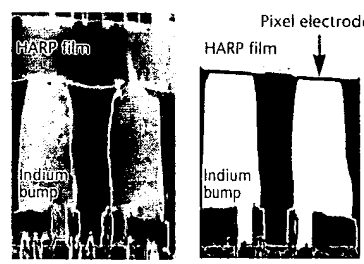
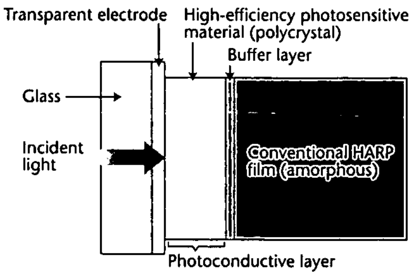


Figure 2: Sectional view of prototype device joint (sectional SEM image 4000 times)

We also initiated the development of a new, ultrahigh-speed, high-sensitivity, solid-state imaging device, and examined the possible application to this new device of the element technologies accumulated through the research on solid-state HARP devices, including precision processing.

3.4.3 Photoconductive Film

Aiming to develop a HARP film with higher sensitivity and a better signal-to-noise ratio, work progressed on a 35μ m thick New Super-HARP film (charge multiplication factor of approx. 1200). Based on the findings obtained through the research on a 25μ m thick New Super-HARP film (charge multiplication factor of approx. 600), a film structure was designed that can prevent pattern distortion and false signals at the edge of the picture, which becomes an issue as film thickness is increased. We also worked on the establishment of basic film deposition technology that will enable the production of New Super-HARP film with a uniform thickness of 35μ m. A new research project was also started to develop advanced HARP film with a photoconversion efficiency of nearly 100% across the entire visible light spectrum, which is the theoretical limit. In this research, we devised and test manufactured a HARP film with a new structure (figure). This structure employs polycrystal photosensitive material, which shows high photoconversion efficiency for the whole visible light spectrum, as the photoconductive layer of a HARP film. Experimental results indicated that the prototype film can obtain a good photoconversion efficiency of 80% or higher across the visible light spectrum, and a stable image can be obtained thanks to the smooth charge-transfer from the polycrystal material to the amorphous material. These results hold promise for advanced high-efficiency HARP film fabrication.



Advanced high-efficiency HARP film structure

Studies also continued on a highly functional photoconductive film using organic material with the aim of realizing a next-generation high-performance single-plate color imaging device that will make prism unnecessary in TV cameras. A 2001 prototype wavelength-selective organic photoconductive film had a photoconversion efficiency of approximately 1%. In fiscal 2002, we performed new studies on film structure and deposition methods. We also manufactured a prototype film that connects electron transport and hole transport materials. Such investigations contributed to an improvement of photoconversion efficiency of 10% or higher.

Targeting highly sensitive and functional solid-state imaging devices, we continued studies on advanced photoconductive film utilizing silicon nano-crystal. While thicker photoconductive film is an important factor in generating the charge multiplication phenomenon expected in the silicon nanodot multilayer, the conventional fabrication process had only a slow deposition rate. To solve this problem, a processing technology was devised in fiscal 2002 that triples the deposition rate, which holds promise for film thickening. Work on optimization of the silicon nanodot multilayer structure also progressed, confirming control of the gap between the silicon nanodots will increase photoconversion efficiency.

Chapter 1. Introduction

1-1. Basic Concept of TFT-LCD

1-1-1. Motivation and overview of the thesis

There has been a growing demand for flat panel displays (FPDs) in many fields such as office automation equipments, consumer electronics, portable personal devices, and vehicle applications [1]. A flat panel display reduces equipment volume and weight compared to the conventional cathod-ray tube (CRT). The flat panel displays, which have been successfully developed to products, are plasma display panel (PDP), electroluminescent displays (ELDs), vacuum fluorescent displays (VFDs), field emission displays (FEDs) and liquid crystal displays (LCDs). Of these, the liquid crystal display (LCD) is superior in its full-color display capabilities and low power consumption, the other methods lacking in brightness and luminance efficiency, especially in the blue color [1]. Although full color LCD is still medium in size, 3 to 30 inches in diagonal, the full-color liquid crystal multimedia displays are now available on the market.

The liquid crystalline state has been discovered about 100 years ago when the Austrian botanists F. Reinitzer and O. Lehmann investigated some esters of cholesterol in 1888. And then, dynamic scattering mode (DSM) liquid crystal display, though now obsolete, was the first popular electro-optical display application of liquid crystalline materials [2, 3]. The idea of using liquid crystals for display application was probably first conceived by G. Heilmeier and R. Williams at David Sarnoff Research Centre, then a research wing of RCA corporation in New Jersey, USA, in 1963 [4-6]. These dynamic scattering mode diplays had many advantages over other displays, such as CRT (cathod ray tube), LED (light emission diode), electroluminescent and plasma, available at that time.

Many researchers and engineers have been engaged in improving the characteristics of liquid crystal displays since that time. Much research into active matrix LCDs has been reported [7-10]. The first AMLCD was successfully demonstrated by Brody in 1973, where a CdSe TFT was used as a switching element for each pixel of a 120¡¿120 matrix [8]. After LeComber reported the first amorphous hydrogenated silicon (a-Si:H) TFT [11], many laboratories started the development of AMLCDs using a-Si:H TFTs formed on glass substrate. Color displays have also been realized by the use of color filters in the transmission mode. AMLCDs currently available on the market use a-Si:H TFTs, polycrystalline silicon (poly-Si) TFTs, and metal-insulator-metal (MIM) two-terminal nonlinear devices. These products are mainly found in portable color television sets and screen sizes still have between only 3 to 21 inches in diagonal.

Two trends have appeared in the development of TFT-LCD. One is the direct-view displays for use in portable computers and television receivers, where LCDs with larger screen sizes and higher pixel-content are required [9-10]. The other is toward compact LCD modules with high pixel density for use in projection television sets and video cameras as monitor display [11]. A-Si:H TFT-LCDs have been widely used for many applications in direct view displays such as PC/WSs, AV/TVs, and various monitors. During the last 10 years, LCD screen size has rapidly increased from 3 to 21 inch diagonals, and larger ones of over 21 inches have been demonstrated at several exhibitions. Small-size LCDs with high pixel densities are also used as light valves for LCD projectors and viewfinders for videocameras. Poly-Si TFTs are suitable for such applications because the monolithic drivers around the screen preclude a limit on connector pitches between driver ICs and display signal lines.

As mentioned above, LCDs is a promising technology for realizing high quality interface such as information displays, projector, and portable personal devices. This is because LCDs have unique and

superior features such as compactness, thin, light and low-power consumption in principle. The drastic improvement of thin film transistor (TFT) has the key to attain the high performance TFT-LCDs, i.e., high speed, high density, and high gray-scale and large area.

In chapter 1 of this thesis, the historical review of the poly-Si TFT technologies is presented. In Chapter 2, the advantages and disadvantages for the various TFT structures and gate insulators using ELA poly-Si are described. As a gate insulator material, silicon nitride has some advantages such as large area capability, good insulating properties, high breakdown field and use of conventional PECVD system.

In Chapter 3, a macroscopic theory of laser annealing is given. Especially heat transport and melting phenomena during ELA of a-Si are summarized, and the grain growth mechanism is introduced. The ELA system used in this work is introduced in Chpater 4. The deposition conditions of a-Si:H and SiNx films by PECVD are also described in Chapter 4. And then, the electrical and structural properties of ELA poly-Si film are described in Chapter 5.

Many researchers have studied the anomalous leakage current of poly-Si TFT. It is very important in pixel switching element to reduce the flicker in TFT-LCD. Therefore, the leakage current mechanisms that were reported by the pioneer groups are summarized. In this thesis the novel poly-Si TFT was proposed to decrease the leakage current. Field enhanced tunneling via lowering barrier height by induced drain field governs it.

In Chapter 6, the performance of advanced poly-Si TFT is discussed. First, to utilize the SiNx as an ion stopper and gate insulator, the novel poly-Si TFT with SiNx ion stopper is fabricated in section 6-2. Second, to reduce the leakage current, the vertical a-Si:H offset poly-Si TFT is proposed. The performance of the novel TFT is characterized in section 6-3. Third, to reduce mask steps, the novel self-aligned poly-Si TFT with Ni silicide S/G/D electrodes is proposed in section 6-4, and then characterized the performance and bias-stress effect on ELA poly-Si TFT. The bias stress effects on ELA poly-Si TFT with SiNx gate insulator are investigated. As well as, to realize small size poly-Si TFT, the short channel poly-Si TFT with high mobility above 100 cm^2/Vs is fabricated. Finally, the bias-stress effects on the ELA poly-Si TFT with SiNx gate insulator are discussed in section 6-5. In Chapter 7, the conclusions for my thesis are given.

1-1-2. Principle of liquid crystal display

There are three phases, crystal, liquid and vapor, in ordinary materials. However, liquid crystal has fourth, mesomorphic state, even in room temperature. Namely, liquid crystal exhibits liquid-like properties and crystal-like properties simultaneously. This feature results from long length of the molecule and the orientational orderness in their molecular arrangement. The unique molecular arrangement allows dielectric anisotropy, which is very important realizing liquid crystal display. Figure 1-1 shows the construction and operation of a transmissive type twisted nematic field effect (TN-FE) mode liquid crystal cell[9].

The cell consists of two glass substrates coated on their inner surfaces with transparent electrode and separated by several μm from each other. A nematic liquid crystal material fills the space between the two substrates. Since two glass substrates, each having alignment layer, are oriented with their alignments perpendicular to each other, liquid crystal molecule is twisted initially. And because also the polarizer is oriented perpendicular, the light whose polarity is twisted by the liquid crystal is transmitted through the polarizer of output initially as shown Fig. 1-1(a). When a voltage is applied, since liquid

crystal materials have positive dielectric anisotropy, the director of the molecules tends to orient itself parallel to the applied field as shown in Fig. 1-1(b). Because the polarization of light transmitted through liquid crystals is different from the polarizer of output, the light is cut off. Consequently, the light is switched by using dielectric anisotropic characteristics of liquid crystal.

a) Simple Matrix LCDs

The driving method of LCDs is dividing roughly into simple (passive) matrix and active matrix. Simple matrix type [12] was used in the first stage of LCDs. In this method, the transparent electrodes are set on X and Y axis as shown in Fig. 1-2.

The some character or image can be displayed using the following sequence. The horizontal (row) electrodes are selected from the top to the bottom. When the first row electrode is selected, the third vertical (column) electrode is selected simultaneously. When the second row electrode is selected, the second and the fourth column electrode is selected simultaneously, and so on. In this method, however, because all electrodes are electrically connected together, small voltage is added to the pixel, which should be off state too. Thus it is difficult to get high contrast for the large or the high definition, i.e., increase in the number of matrix. Therefore the liquid material was improved to overcome this problem. For example, double layered super twisted nematic (DSTN) mode, which is twisted quickly up to the voltage, was produced to allow color display. But this method still has the inherent problem that each pixel can not be switched completely even though the structure is simple, i.e., the production cost is low.

b) Active Matrix LCDs

The structure of a TFT-LCD is basically very similar to that of a diode-matrix LCD. As stated in the section a), TN-mode LCDs are of two types according to display mode: the reflection type and the transmission type. For an AMLCD, the transmission mode is generally used in the case of a color display. The configuration of a typical color AMLCD is shown in Figure 1-3. The display operates in the transmission mode with fluorescent lamp behind the panel. The panel consists of two glass plates: the bottom and top glass substrates. The bottom substrates are stacked together with the TFT side facing the color filter side. Liquid crystal material is injected between these two glass plates, filling the small gap of around several micrometers with extreme uniformity. In general, a twisted nematic (TN) LC mode is used, so the panel needs a polarizer film on the outer surface of each glass substrate.

The pixels are arranged in a x-y matrix formed on the bottom glass substrate. Each pixel has an a-Si:H TFT which operates as an analogue switch to control the stored charge in an LC capacitor. The capacitance is defined between the pixel electrode on the bottom substrate and a common electrode on the top substrate. The color filter layer on the top glass substrate consists of the three primary chromaticities: red, green, and blue. Each color dot coincides with the corresponding pixel electrode.

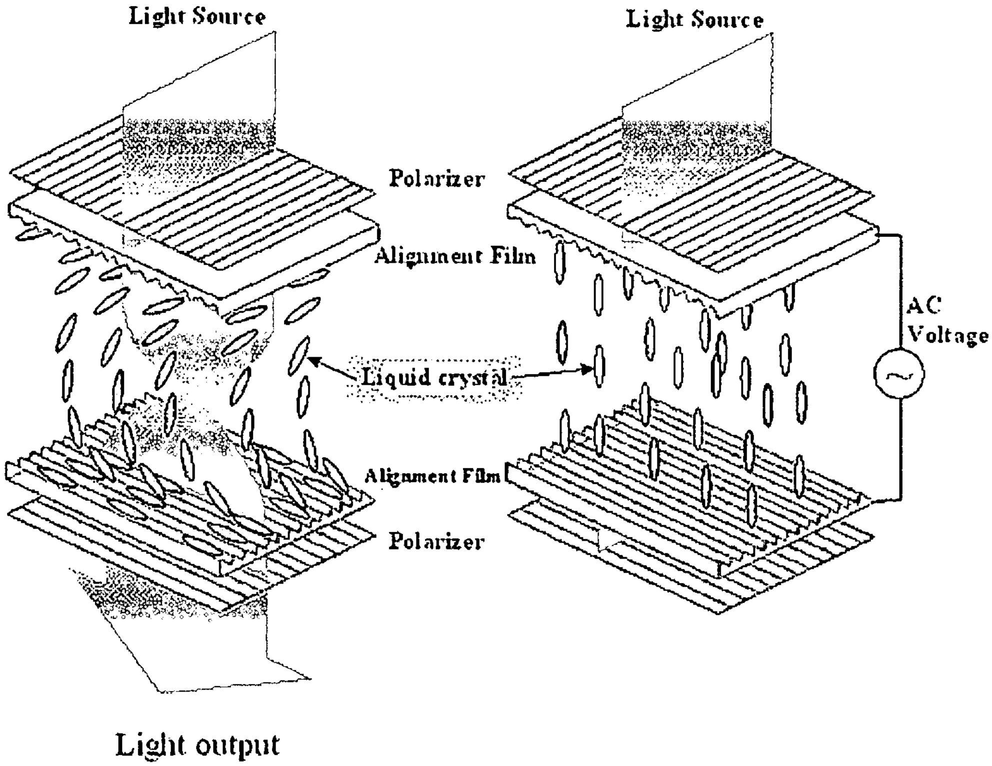


Fig. 1-1. Operation of twisted nematic field effect mode liquid crystal cell.

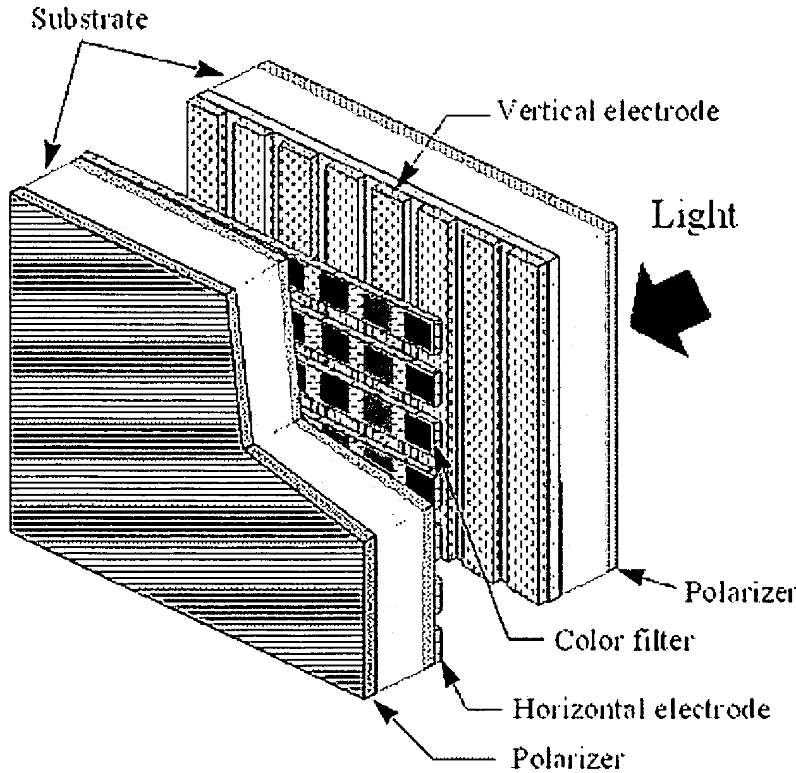


Fig. 1-2. Schematic representation of simple matrix LCDs.

Figure 1-4 shows a schematic diagram of the TFT-LCD array with controllers, a power supply, and other driver circuits. The TFT substrate consists of a TFT array and an array of external terminals on which large-scale integrations (LSIs) are bonded to drive the TFT panel. The drivers LSIs are essentially scan generators for the horizontal and vertical buslines. These LSIs are directly bonded to the glass with tape automated bonding (TAB) connectors, and they provide each pixel of the panel with video signals that are transferred to the panel via a video signal processor and controller.

Poly-Si TFTs are suitable for such applications because the monolithic drivers around the screen precludes a limit on connector pitches between driver ICs and device specifications are fufilled by high temperature processes of about 1000 °C. Many researchers have studied the fabrication of the TFT-LCD with chip on glass (COG) in the same glass plate by using ELA poly-Si TFT driver instead of driver ICs and VRAM board. Recently, fabrication of such poly-Si TFT-LCD panels with VGA pixel size and monolithic drivers has been reported [13-15]. Monolithic drivers will reduce the cost of TFT-LCDs. High pixel density panels will also be possible with ELA poly-Si TFTs. These advantages will be suitable for high pixel density midsize panels such as high definition personal digital assistants (PDAs), mobile PCs, single panel LCD projectors, and so on.

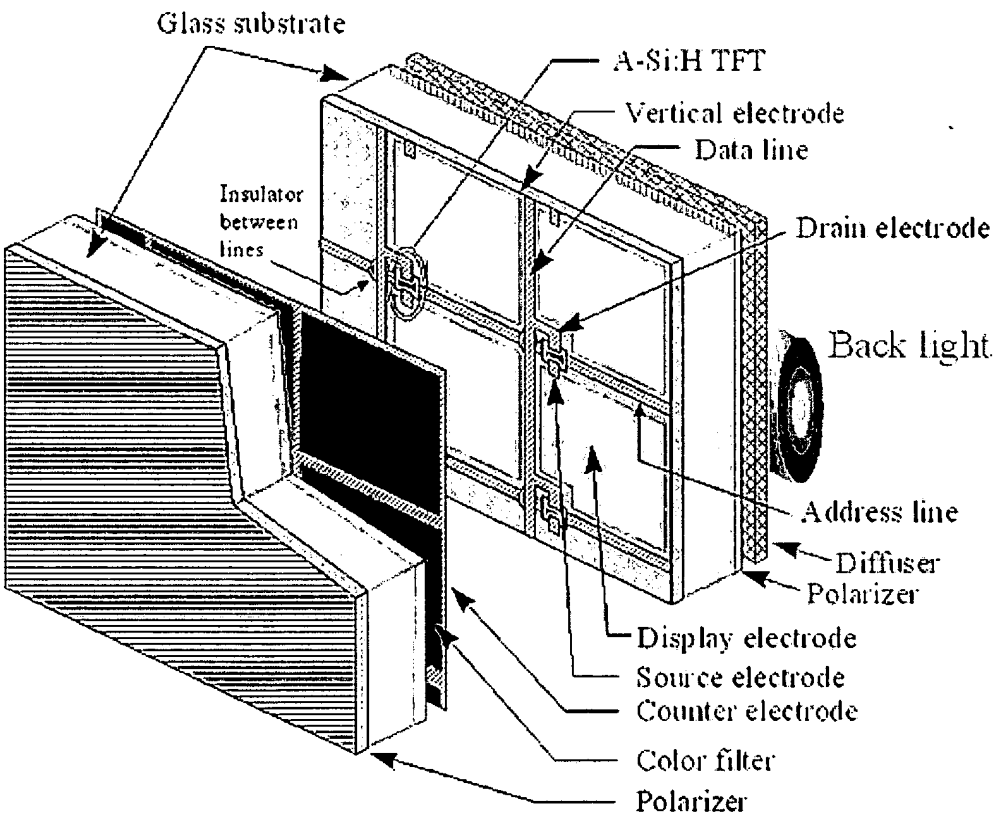


Fig. 1-3. Basic configuration of an AMLCD; this structure is the typical transmissive color TFT-LCD.

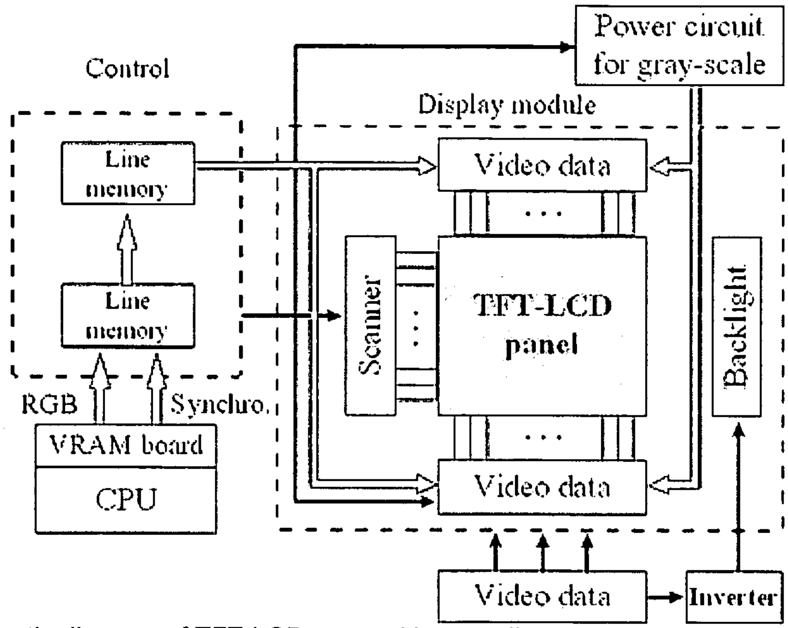


Fig. 1-4. A schematic diagram of TFT-LCD array with controllers, power supply, and driver circuits.

1-2. Historical Review of Poly-Si TFT

An active matrix LCD having a diagonal size of 40" has been reported using the technology of a-Si:H. With increasing the display area and pixel density of TFT-LCD, high mobility TFTs are required for pixel driver of TFT-LCD in order to shorten the charging time of pixel electrodes. However, it is very difficult because a-Si:H have low mobility. The problem of the low carrier mobility for a-Si TFTs can be overcome easily by introducing polycrystalline Si (poly-Si) film instead of a-Si as a semiconductor layer of TFTs. The poly-Si is the most promising material for obtaining such high mobility TFTs for pixel drivers, moreover, the peripheral driver circuits can be integrated on the same substrate. Therefore, the poly-Si TFT has gained increasing interest and has been investigated by many researchers [16-19].

The recrystallization techniques are essentially suited for wafer-scale processes, whereas Furuta et al. has suited for preferential recrystallization of the desired region of the entire wafer. Because the melting at surface-near region occurred, crystallinity of the surface-near region seeded from the underlaid poly-Si layer. Especially, fabricating poly-Si TFTs at a temperature much lower than a strain point of a glass substrate is needed in order to have high mobility TFTs on large-area glass substrate.

In general, the fabrication technique of poly-Si film is divided simply into four by the environmental during the growth such as as-deposited, solid phase crystallization (SPC), pulsed rapid thermal annealing (PRTA) and excimer laser annealing (ELA) [20-23]. The most conventional method to fabricate poly-Si is low pressure chemical vapor deposition (LPCVD) [24]. However, this method have some disadvantages such as high deposition temperature over 600¡É, small grain size < 50 nm, poor crystallinity and high grain boundary states. So that the low temperature and large area processes using a cheap glass substrate are impossible because of high temperature process. To enhance crystal properties, SPC is more useful method to increase the grain size than the as-deposited poly-Si film by LPCVD [21]. But it needs a long time annealing at high temperature over 600¡É. On the other hand, PECVD can be available to fabricate poly-Si film by using $SiF_4/SiH_4/H_2$/He mixture gas at below 450¡É [20, 25]. However, the as-deposited poly-Si films have some problems such as poor crystallinity and small grain

size. The grain size depends on the thickness of the poly-Si layer.

Meanwhile, there are liquid phase recrystallization methods such as zone melting regrowth (ZMR) and ELA, which enable us to have good quality poly-Si film with large grain size and good electrical properties. In the case of ZMR, the temperature of whole substrate increase up to about the melting temperature of a-Si, nearly ¡ 1000 ¡É, at which glass substrate can not be applied. On the other hand, PRTA was suggested presently for the better process at low temperature < 800 ¡É [22]. The PRTA is not distorting the glass substrate, because the pulsing time is very short to decrease glass damage. On the contrary, ELA technology can be fabricate the low temperature poly-Si TFT-LCDs without mechanical stress of glass substrate.

In the crystallization procedures at low temperature, a laser annealing method is a promising process for obtaining a high quality poly-Si films on a cheap glass substrate [23]. In order to fabricate poly-Si TFTs at a low temperature, it is essential to form high quality poly-Si films and to form a good SiO_2/Si interface at a low temperature. Laser crystallization can be provides a good crystalline silicon films to utilize TFT with mobility higher than 100 cm^2/Vs at low temperature below 500 ^oC [26-29]. In general, however, poly-Si TFTs can not have good characteristics if the SiO_2 /poly-Si interface is not good, because high interface trap density can cause a high threshold voltage and low field effect mobility. Several methods for good gate insulator, which is obtainable low interface states, have been developed [30-33].

Many researchers recently have studied the fabrication of high performance poly-Si TFTs with low leakage current, high mobility, high on/off current ratio, and good uniformity. To utilize the high quality TFT-LCD without cross-talk, flicker and image sticking, needs poly-Si TFT with low leakage current below ~ 10^{-12} A/ ?m. In this these, the key factors for high performance poly-Si TFT-LCDs are described. A novel structures of poly-Si TFTs have been proposed in order to obtain the important factors such as low leakage current, reduction of process steps and high field effect mobility.

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References

[1] W.E. Howard, Proc. of Japan Display 89, 8 (1989)
[2] B. Bahadur, Mol. Cryst. Lig. Cryst. **99**, 345 (1983)
[3] J.A. Castellan, Mol. Cryst. Liq. Cryst. **165**, 389 (1988)
[4] R. Williams, J. Chem. Phys. **39**, 384 (1963)
[5] R. Williams and G.H. Heilmeier, J. Chem. Phys. **44**, 638 (1966)
[6] G.H. Heilmeier, L.A. Zanoni and L.A. Barton, Appl. Phys. Lett. **13**, 46 (1968)
[7] B.J. Lechner, F.J. Marlowe, E.O. Nester and J. Yults, Proc. IEEE Trans. Electron Devices **59**, 1566 (1971)
[8] T.P. Brody, J.A. Asars and G.D. Dixon, IEEE Trans. Electron Devices **ED-20**, 995 (1984)
[9] H. Tanaka, S. Molte, M. Hoshino, K. Takahashi, M. Ohta, T. Sakai and T. Yamazaki, Tech. Digest of SID 87, 140 (1987)
[10] K. Oki, Y. Nasu, J. Inoue, T. Hoshiya, K. Takahara and Y. Toyama, Proc. of Euro Display 87, 55 (1987)
[11] P.G. Lecomber, W.E. Spear and A. Ghaith, Electron Lett. **15**, 179 (1979)
[12] K. Ichikawa, S. Suzuki, H. Matino, T. Aoki, T. Higuchi and Y. Oana, Tech. Tech. Digest of SID 89, 226 (1989)
[13] M. Katayama, A. Imaya, N. Nakazawa, H. Kato, K. Yano, H. Fukuoka, Y. Kanatani, Y. Ito and M. Hijikigawa, Proc. of Japan Display 89, PD-6 (1989)
[14] T. Takubo, M. Takeda, T. Tamura, H. Iwai, K. Ukita, Y. Bessho and I. Yamashita, Proc. of Japan Display 89, 584 (1989)
[15] M. Schadt and W. Helfrich, Appl. Phys. Lett. **184**, 127 (1971)
[16] J.A. van Raalte, Proc. IEEE Trans. Electron Devices **56**, 2146 (1968)
[17] E. Fujii, K. Senda, F. Emoto, A. Yamamoto, A. Nakamura, Y. Uemoto and G. Kano, IEEE Trans. Electron

Learn About LCD TV and TFT LCD Displays

TFT LCD TV - What is TFT LCD?

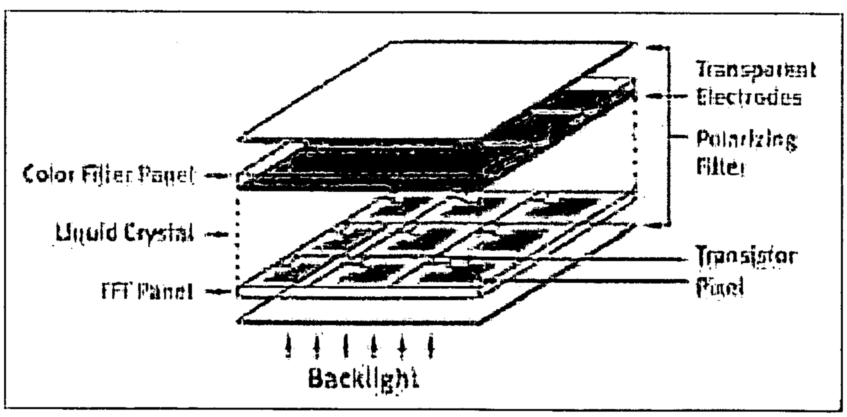
History of TFT LCD

Liquid crystal was discovered by the Austrian botanist Fredreich Rheinizer in 1888. "Liqui
is neither solid nor liquid (an example is soapy water).

In the mid-1960s, scientists showed that liquid crystals when stimulated by an external el
charge could change the properties of light passing through the crystals.

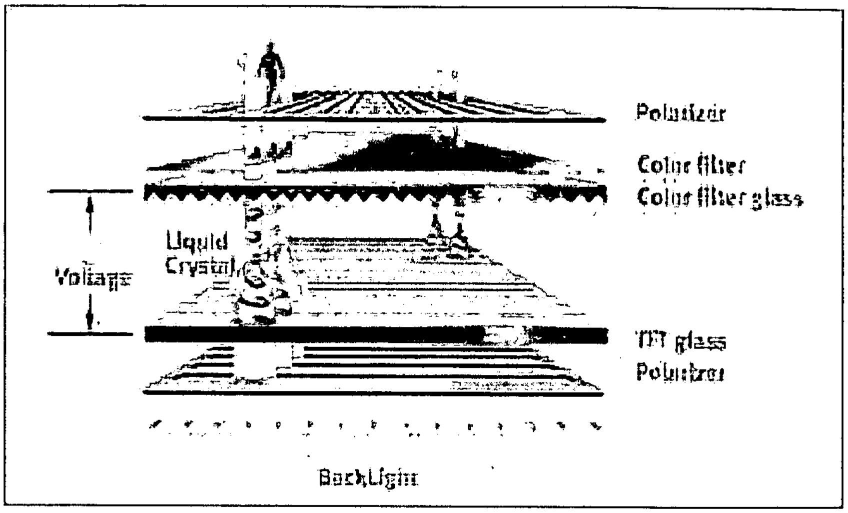
The early prototypes (late 1960s) were too unstable for mass production. But all of that cl
when a British researcher proposed a stable, liquid crystal material (biphenyl).

Today's color LCD TVs and LCD Monitors have a sandwich-like structure (see figure belc



What is TFT LCD?

TFT LCD (Thin Film Transistor Liquid Crystal Display) has a sandwich-like structure with
crystal filled between two glass plates.



TFT Glass has as many TFTs as the number of pixels displayed, while a Color Filter Glas color filter which generates color. Liquid crystals move according to the difference in volta between the Color Filter Glass and the TFT Glass. The amount of light supplied by Back determined by the amount of movement of the liquid crystals in such a way as to generat

TFT LCD - Electronic Aspects of LCD TVs and LCD Monitors

Electronic Aspects of AMLCDs

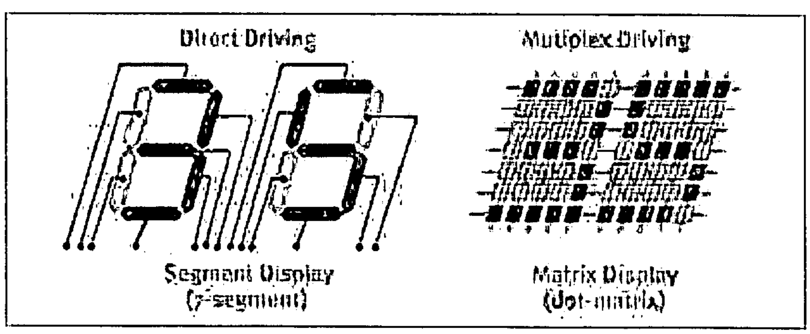
The most common liquid-crystal displays (LCDs) in use today rely on picture elements, o formed by liquid-crystal (LC) cells that change the polarization direction of light passing th them in response to an electrical voltage.

As the polarization direction changes, more or less of the light is able to pass through a p layer on the face of the display. Change the voltage, and the amount of light is changed.

There are two ways to produce a liquid-crystal image with such cells: the segment driving and the matrix driving method.
The segment driving method displays characters and pictures with cells defined by patter electrodes.

The matrix driving method displays characters and pictures in sets of dots.

Direct vs. multiplex driving of LCD TVs.



The segment drive method is used for simple displays, such as those in calculators, whil‹ matrix drive method is used for high-resolution displays, such as those in portable compu TFT monitors.

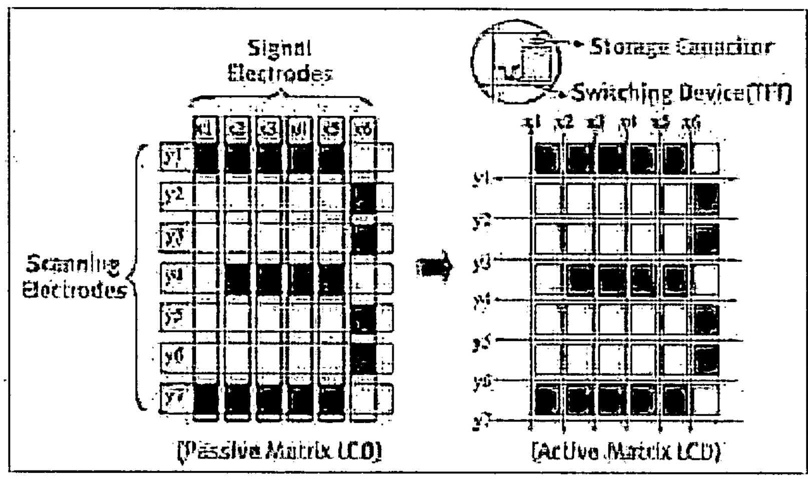
Two types of drive method are used for matrix displays. In the static, or direct, drive meth pixel is individually wired to a driver. This is a simple driving method, but, as the number ‹ is increased, the wiring becomes very complex. An alternative method is the multiplex dri method, in which the pixels are arranged and wired in a matrix format.

To drive the pixels of a dot-matrix LCD, a voltage can be applied at the intersections of s| vertical signal electrodes and specific horizontal scanning electrodes. This method involv several pixels at the same time by time-division in a pulse drive. Therefore, it is also calle multiplex, or dynamic, drive method.

Passive and Active Matrix LCDs

There are two types of dot-matrix LCDs.

Passive-matrix vs. active-matrix driving of LCD Monitors.



In passive-matrix LCDs (PMLCDs) there are no switching devices, and each pixel is addr more than one frame time. The effective voltage applied to the LC must average the sign pulses over several frame times, which results in a slow response time of greater than 15 and a reduction of the maximum contrast ratio. The addressing of a PMLCD also produc‹ of crosstalk that produces blurred images because non-selected pixels are driven througl secondary signal-voltage path. In active-matrix LCDs (AMLCDs), on the other hand, a sw device and a storage capacitor are integrated at the each cross point of the electrodes.

The active addressing removes the multiplexing limitations by incorporating an active swi element. In contrast to passive-matrix LCDs, AMLCDs have no inherent limitation in the r scan lines, and they present fewer cross-talk issues. There are many kinds of AMLCD. F‹ integrated switching devices most use transistors made of deposited thin films, which are called thin-film transistors (TFTs).

The most common semiconducting layer is made of amorphous silicon (a-Si).
a-Si TFTs are amenable to large-area fabrication using glass substrates in a low-temper‹ (300°C to 400°C) process.

An alternative TFT technology, polycrystalline silicon - or polysilicon or p-Si-is costly to pr and especially difficult to fabricate when manufacturing large-area displays.

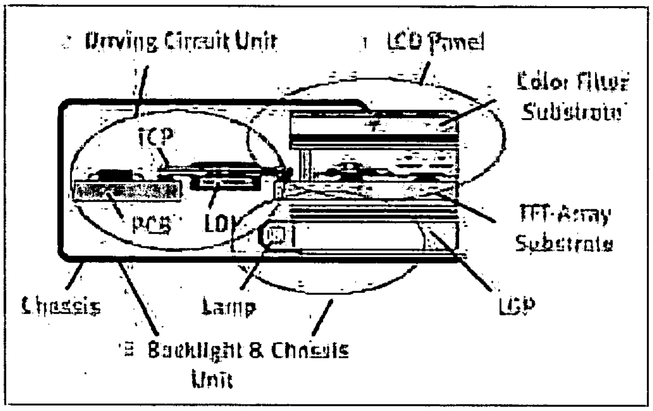
Nearly all TFT LCDs are made from a-Si because of the technology's economy and matu the electron mobility of a p-Si TFT is one or two orders of magnitude greater than that of a TFT.

This makes the p-Si TFT a good candidate for an TFT array containing integrated drivers likely to be an attractive choice for small, high definition displays such as view finders and projection displays.

Structure of Color TFT LCD TVs and LCD Monitors

A TFT LCD module consists of a TFT panel, driving-circuit unit, backlight system, and as: unit.

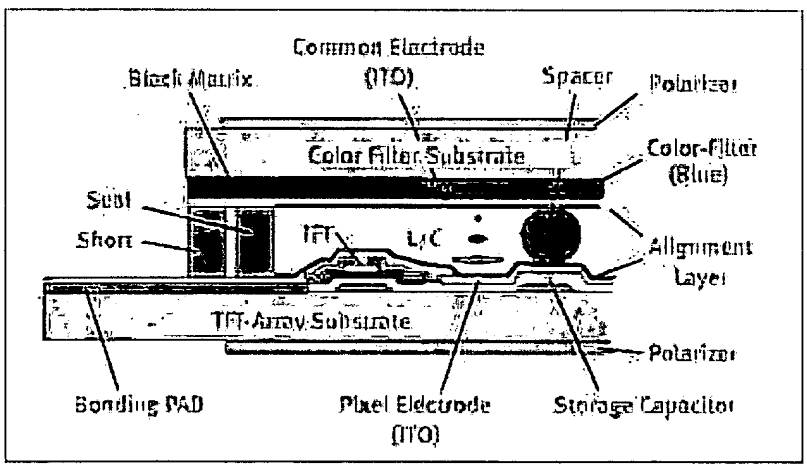
Structure of a color TFT LCD Panel:



1. LCD Panel
   - TFT-Array Substra
   - Color Filter Substr
2. Driving Circuit Unit
   - LCD Driver IC (LD
   - Multi-layer PCBs
   - Driving Circuits
3. Backlight & Chassis
   - Backlight Unit
   - Chassis Assembly

It is commonly used to display characters and graphic images when connected a host sy: The TFT LCD panel consists of a TFT-array substrate and a color-filter substrate.

The vertical structure of a color TFT LCD panel.



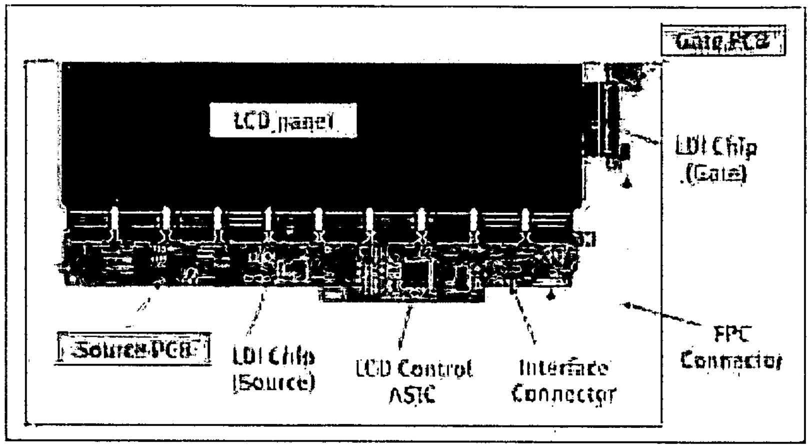
The TFT-array substrate contains the TFTs, storage capacitors, pixel electrodes, and inte wiring. The color filter contains the black matrix and resin film containing three primary-cc green, and blue - dyes or pigments. The two glass substrates are assembled with a seala gap between them is maintained by spacers, and LC material is injected into the gap bet substrates. Two sheets of polarizer film are attached to the outer faces of the sandwich fc the glass substrates. A set of bonding pads are fabricated on each end of the gate and d:

bus-lines to attach LCD Driver IC (LDI) chips

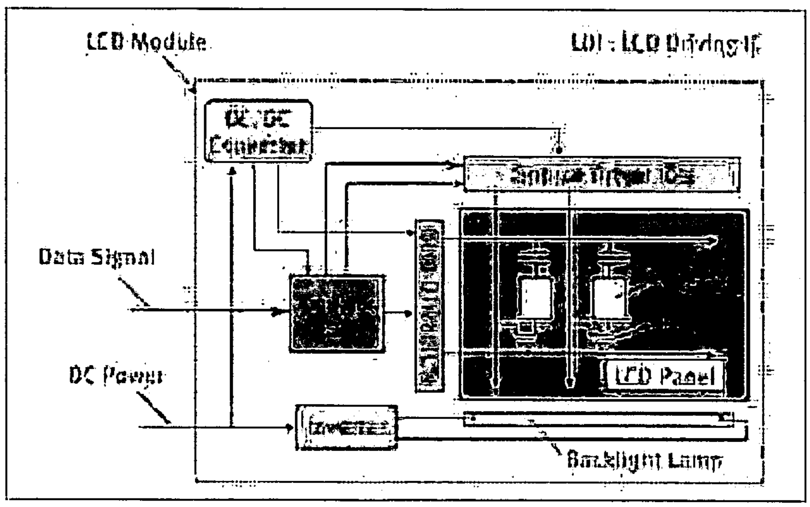
Driving Circuit Unit

Driving an a-Si TFT LCD requires a driving circuit unit consisting of a set of LCD driving I chips and printed-circuit-boards (PCBs).

The assembly of LCD driving circuits.



A block diagram showing the driving of an LCD panel.

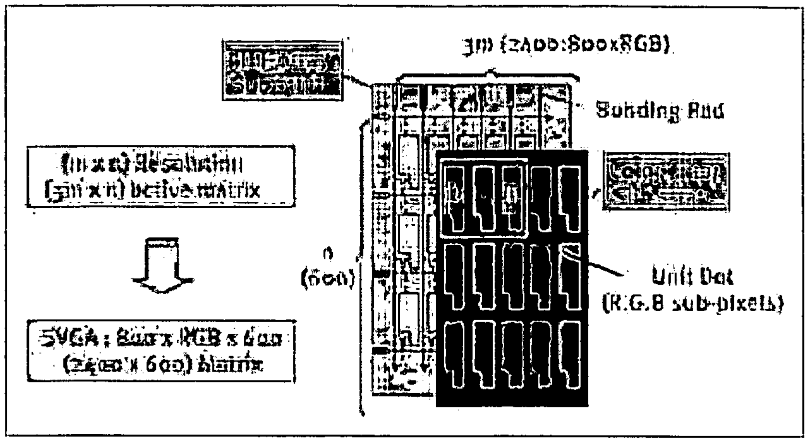


To reduce the footprint of the LCD module, the drive circuit unit can be placed on the bac the LCD module by using bent Tape Carrier Packages (TCPs) and a tapered light-guide (LGP).

How TFT LCD Pixels Work

A TFT LCD panel contains a specific number of unit pixels often called subpixels.
Each unit pixel has a TFT, a pixel electrode (IT0), and a storage capacitor (Cs).
For example, an SVGA color TFT LCD panel has total of 800x3x600, or 1,440,000, unit p
Each unit pixel is connected to one of the gate bus-lines and one of the data bus-lines in matrix format. The matrix is 2400x600 for SVGA.

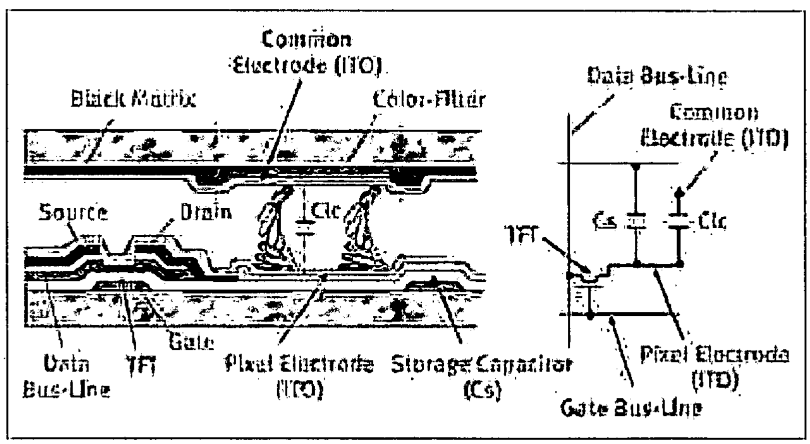
Structure of a color TFT LCD panel.



Because each unit pixel is connected through the matrix, each is individually addressable
bonding pads at the ends of the rows and columns.
The performance of the TFT LCD is related to the design parameters of the unit pixel, i.e.
channel width W and the channel length L of the TFT, the overlap between TFT electrode
sizes of the storage capacitor and pixel electrode, and the space between these element
The design parameters associated with the black matrix, the bus-lines, and the routing of
lines also set very important performance limits on the LCD.

In a TFT LCD's unit pixel, the liquid crystal layer on the ITO pixel electrode forms a capac
whose counter electrode is the common electrode on the color-filter substrate.

Vertical structure of a unit pixel and its equivalent circuit



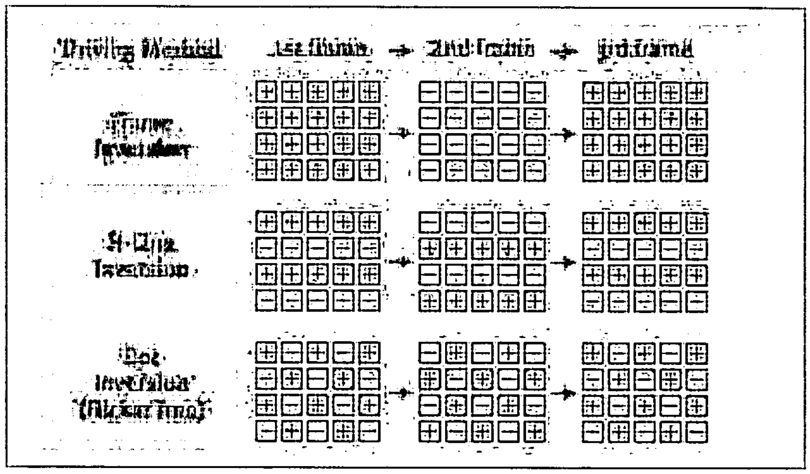
A storage capacitor (Cs) and liquid-crystal capacitor (CLC) are connected as a load on th
Applying a positive pulse of about 20V peak-to-peak to a gate electrode through a gate b
turns the TFT on. Clc and Cs are charged and the voltage level on the pixel electrode rise
signal voltage level (+8 V) applied to the data bus-line.

The voltage on the pixel electrode is subjected to a level shift of DV resulting from a para
capacitance between the gate and drain electrodes when the gate voltage turns from the
OFF state. After the level shift, this charged state can be maintained as the gate voltage
V, at which time the TFT turns off. The main function of the Cs is to maintain the voltage
pixel electrode until the next signal voltage is applied.

Liquid crystal must be driven with an alternating current to prevent any deterioration of im
quality resulting from dc stress.
This is usually implemented with a frame-reversal drive method, in which the voltage app

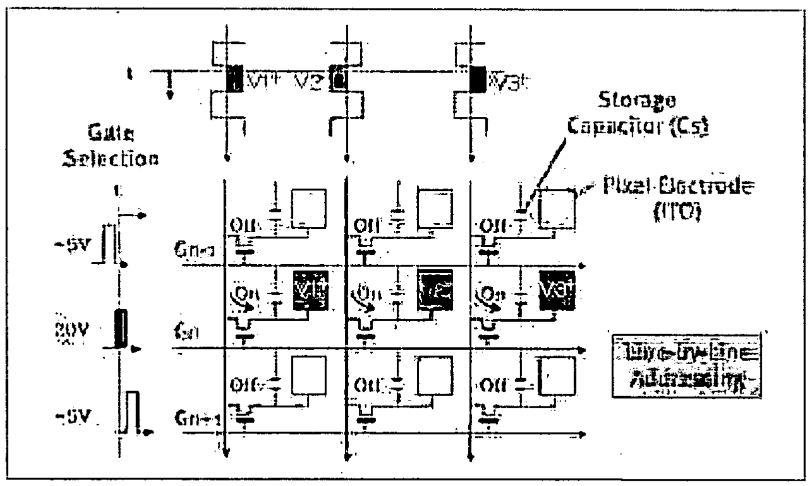
each pixel varies from frame to frame. If the LC voltage changes unevenly between fram result would be a 30-Hz flicker.
(One frame period is normally 1/60 of a second.) Other drive methods are available that this flicker problem.

Polarity-inversion driving methods.



In an active-matrix panel, the gate and source electrodes are used on a shared basis, bu unit pixel is individually addressable by selecting the appropriate two contact pads at the the rows and columns.

Active addressing of a 3x3 matrix



By scanning the gate bus-lines sequentially, and by applying signal voltages to all source in a specified sequence, we can address all pixels. One result of all this is that the addre an AMLCD is done line by line.

Virtually all AMLCDs are designed to produce gray levels - intermediate brightness levels the brightest white and the darkest black a unit pixel can generate. There can be either a numbers of levels - such as 8, 16, 64, or 256 - or a continuous gradation of levels, depen the LDI.

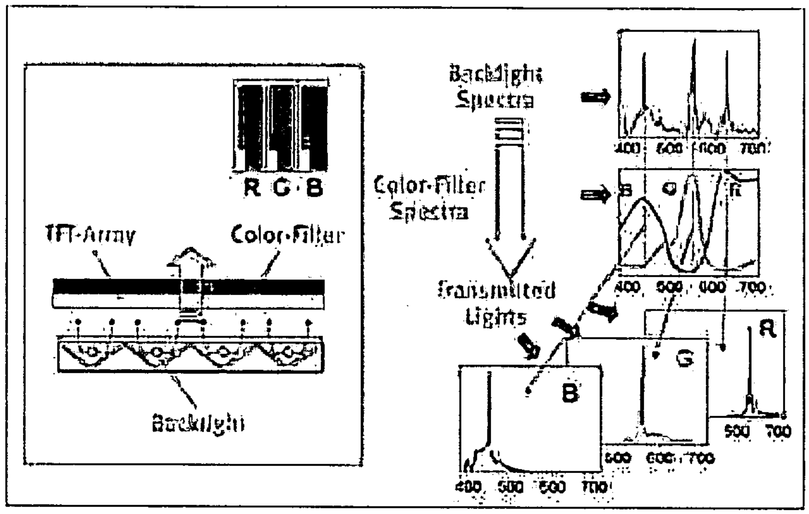
The optical transmittance of a TN-mode LC changes continuously as a function of the ap voltage.

An analog LDI is capable of producing a continuous voltage signal so that a continuous r gray levels can be displayed.
The digital LDI produces discrete voltage amplitudes, which permits on a discrete numbe shades to be displayed. The number of gray levels is determined by the number of data b produced by the digital driver.

Generating Colors

The color filter of a TFT LCD TV consists of three primary colors - red (R), green (G), anc - which are included on the color-filter substrate.

How an LCD Panel produces colors.



The elements of this color filter line up one-to-one with the unit pixels on the TFT-array su Each pixel in a color LCD is subdivided into three subpixels, where one set of RGB subpi equal to one pixel.
(Each subpixel consists of what we've been calling a unit pixel up to this point.)

Because the subpixels are too small to distinguish independently, the RGB elements app human eye as a mixture of the three colors.
Any color, with some qualifications, can be produced by mixing these three primary color:

The total number of display colors using an n-bit LDI is given by 23n, because each subp generate 2n different transmittance levels.

Continue by clicking on one of the following links:

		NEXT Fabricating TFT L

We would like to express our appreciation to Samsung Electronics for the preceding infor